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REVISION OF THE SOUTH AMERICAN SPECIES OF CUSCUTA

II

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Section CLISTOGRAMMICA Engelmänn

KEY TO THE SUBSECTIONS

- Flowers not subtended by bracts; calyx segments more or less united.....PLATYCARPAE.
Flowers subtended by numerous bracts; calyx segments mostly free (no
members of this subsection have been found from South America).....LEPIDANCHE.

Subsection PLATYCARPAE Engelmänn

KEY TO THE SPECIES

- Calyx lobes obtuse (acutish in *C. gymnocarpa*, *C. suaveolens*, and *C. parviflora*).
Calyx lobes mostly not overlapping, or but slightly so, mostly smooth.
Styles becoming subulate and divaricate in fruit.....25. *C. obtusiflora*.
Styles not becoming noticeably subulate in fruit (subulate in *C. pentagona subulata*).
Flowers mostly more than 2 mm. long.
Scales prominent, withered corolla about the capsule or at its base.
Corolla lobes acute.
Calyx nearly as long as the corolla, lobes ovate, may be slightly overlapping, corolla lobes upright or reflexed.
Corolla lobes spreading or reflexed, tips inflexed.....26. *C. pentagona*.
Corolla lobes upright.....27. *C. gymnocarpa*.
Calyx much shorter than the corolla, lobes triangular, not at all overlapping, corolla lobes upright, tips inflexed.....28. *C. suaveolens*.
Corolla lobes mostly obtuse.
Calyx lobes not overlapping.....29. *C. racemosa*.
Calyx lobes more or less overlapping.....30. *C. platyloba*.

[The Journal for December (9: 535-581) was issued Jan. 10, 1923.]

- Scales narrow, not prominent, withered corolla capping the capsule.....31. *C. stenolepis*.
 Flowers mostly less than 2 mm. long.....32. *C. parviflora*.
 Calyx lobes broadly overlapping, frequently keeled.....33. *C. cristata*.
 Calyx lobes acute.
 Flowers fleshy, corolla lobes more or less papillate, tips mostly inflexed.....34. *C. indecora*.
 Flowers not fleshy, corolla lobes not inflexed at the tips.
 Infrastamineal scales present.
 Pedicels mostly longer than the flowers, calyx lobes triangular.....35. *C. globosa*.
 Pedicels no longer than the flowers (mostly shorter), calyx lobes ovate.
 Corolla lobes mostly shorter than the tube.....36. *C. micrantha*.
 Corolla lobes mostly equal to or longer than the tube.....37. *C. acuta*.
 Infrastamineal scales lacking.....38. *C. insquamata*.

25. *Cuscuta obtusiflora* Humboldt, Bonpland, & Kunth
 (Pl. V, fig. 29, A-E)

Cuscuta obtusiflora Humboldt, Bonpland, & Kunth, Nova gen. et spec. pl. 3: 122 (96 in folio edition). 1818.—Engelmann, Trans. Acad. Sci. St. Louis 1: 492. 1859.—Progel in Martius, Flora Brasiliensis 7: 380, Pl. 127, fig. 1. 1871.
Cuscuta inodora Willdenow, in herb., ex Engelmann, Trans. Acad. Sci. St. Louis 1: 492. 1859; in synonym.

Stems medium. Flowers 2-2.5 mm. long, subsessile in dense glomerulate clusters, more or less glandulous; calyx scarcely as long as the corolla; lobes unequal, ovate, obtuse, not overlapping; corolla campanulate; lobes about equal to the tube, ovate, obtuse or more rarely acutish, upright, becoming reflexed in fruit; stamens shorter than or nearly equaling the lobes and commonly placed directly in the sinuses, stout, subulate filaments longer than the oval anthers; scales spatulate, fringed about the top, mostly not reaching the stamens, bridged below the middle; styles about as long as the globose ovary, becoming subulate. Capsule depressed-globose, exposed, with the withered corolla about it towards the base, intrastylar aperture large, styles becoming subulate and divergent; seeds globose, compressed, slightly rostrate, 1.25-1.5 mm. long; hilum linear, perpendicular.

All the specimens from South America belong to Engelmann's variety *vera*. The above description was drawn from Humboldt's type specimen.

Type locality: In the Peruvian Andes. *Distribution*: Colombia, Brazil, and southward to Peru and in Paraguay and Uruguay.

Specimens examined: BRAZIL: Matto Grosso, Corumbá (Hoehe 3016).

COLOMBIA: (Triana, without date or number); Medellín (Triana 2178, and in 1851-57).

PARAGUAY: River Ypacarai (H. S. 3018).

PERU: (Humboldt, the type, a fragment in the Engelmann herbarium).

URUGUAY: (Lorentz 51).

26. *Cuscuta pentagona* Engelm.

For the synonymy, description, and illustration of this species see Yuncker, Ill. Biol. Monogr. 6: 140. 1921.

KEY TO THE SOUTH AMERICAN VARIETIES

Styles slender, not becoming subulate in fruit.

Calyx lobes overlapping, forming angles at the sinuses; flowers relatively small.

typica.

Calyx lobes not at all, or but slightly, overlapping and not forming angles at the sinuses; flowers usually larger.....

calycina.

Styles becoming subulate in fruit, intrastylar opening large.....

subulata.

Cuscuta pentagona typica

Specimens examined: ARGENTINA: Buenos Aires (Venturi 100).

URUGUAY: Montevideo (Fruchard in 1871, and in 1875; Courbon 146).

Cuscuta pentagona calycina Engelm.

Specimen examined: BRAZIL: Itajahy (Ule 487).

Cuscuta pentagona subulata n. var.

Styles becoming subulate, capsule and intrastylar aperture large, scales scarcely reaching, or reaching, the stamens.

Type locality: Maraham, Brazil. *Distribution*: Brazil and Ecuador.

Specimens examined: BRAZIL: (Glaziou 19077 in part); Maraham (Gardner 6068 in part, the type, a fragment in the Engelm. herbarium); Prov. São Paulo (St. Hilaire C 1271); Prov. Santa Catharina (Pabst 565).

ECUADOR: Guayaquil (Jameson 542).

27. *Cuscuta gymnocarpa* Engelm.

(Pl. IV, fig. 22, A-E)

Cuscuta gymnocarpa Engelm., Trans. Acad. Sci. St. Louis 1: 496. 1859.

Stems slender to medium. Flowers about 2 mm. long, becoming 2.5-3 mm. long in fruit with the enlarged capsule, on pedicels about as long as the flowers, in few-flowered, globose, umbellate clusters; calyx slightly shorter than the corolla tube, lobes ovate, obtuse or slightly acutish, not overlapping; corolla campanulate, thin, lobes triangular, acute, upright, with tips frequently inflexed, shorter than the tube; scales reaching the stamens, ovate, fringed with moderate processes, bridged below the middle; stamens shorter than the lobes, anthers oval, about equal to the stout subulate filaments; styles about equal to, or shorter than, the globose ovary. Capsule globose or slightly depressed-globose, the withered corolla remaining at the base, not circumscissile. Seeds two to four in each capsule, about 1.5 mm. long, oval, hilum prominent, oblique or perpendicular.

This species differs from *C. pentagona* in having shorter, upright corolla lobes, shorter filaments, and more globose capsules. It differs from *C. acuta* in having the corolla at the base of the protruding capsule, shorter corolla lobes and styles, and obtuse calyx lobes.

Type locality: "James Island of the Galapagos Group." *Distribution*: Galapagos Islands.

Specimens examined: GALAPAGOS ISLANDS: Albemarle Island, Tagus Cove (Stewart 3092), Cowley Bay (Bauer 205).

28. *Cuscuta suaveolens* Seringe

Cuscuta suaveolens Seringe, Ann. Sci. Phys. Nat. Lyon 3: 519. 1840.—Gay, Hist. de Chile 4: 448. 1849.

Cuscuta corymbosa Choisy, Mém. Soc. Phys. Hist. Nat. Genève 9: 276. 1841; and in De Candolle, Prodr. 9: 456. 1845. Not Ruiz & Pavon.

Cuscuta Hassiaca Pfeiffer, Bot. Zeit. 1: 705. 1843.

Engelmannia migrans Pfeiffer, Bot. Zeit. 3: 674. 1845.

Engelmannia suaveolens Pfeiffer, Bot. Zeit. 4: 21. 1846.

Cuscuta diaphana Wenderoth, Fl. Hassiaca, p. 346. 1846.

Pfeifferia suaveolens Buchinger, Ann. Sci. Nat. Bot. III, 5: 88. 1846.

Cassutha suaveolens Des Moulins, Études organiques sur les Cuscutées, p. 66. 1853.

Cuscuta popayanensis Poeppig in herb., ex Engelmann, Trans. Acad. Sci. St. Louis 1: 505. 1859. Not H. B. K.

Cuscuta chilensis Bertero in sched., ex Engelmann, Trans. Acad. Sci. St. Louis 1: 505. 1859. Not Ker-Gawler.

Cuscuta racemosa chiliana Engelmann, Trans. Acad. Sci. St. Louis 1: 505. 1859.—Yuncker, Ill. Biol. Monogr. 6: 144, figs. 36 and 94. 1921.

? *Cuscuta floribunda* Philippi, Fl. Atac., p. 37. 1860. Not H. B. K.

? *Cuscuta andina* Philippi, Anal. Univ. Chile 90: 225. 1895.

? *Cuscuta racemosa floribunda* Reiche, Anal. Univ. Chile 120: 819. 1907.

? *Cuscuta racemosa andina* Reiche, Anal. Univ. Chile 120: 819. 1907.

Stems slender to medium. Flowers 3–4 mm. long, more or less glandular, membranous, on pedicels mostly shorter than the flowers, in racemose clusters; calyx lobes shorter than the corolla tube, triangular-ovate, acutish, not overlapping, sinuses more or less rounded, edges sometimes revolute; corolla campanulate or funnel-form, becoming globular about the developing capsule; lobes ovate-triangular, upright, with acute, inflexed tips, somewhat shorter than the tube; anthers shorter than the lobes, filaments subulate, about equal to the oval anthers; scales not reaching the stamens (infrequently barely reaching them), oblong-ovate or triangular, fringed with medium processes, bridged below the middle; ovary globose, styles slender, about equal to the ovary. Capsule globose, with the withered corolla about it, not circumscissile, two- to four-seeded, seeds 1.5–2 mm. long, roundish, hilum oblong, perpendicular.

Most of the writers have followed the example of Engelmann in considering this a variety of *C. racemosa* Mart. It is undoubtedly closely related to that species, but it is believed that it exhibits characters that warrant its being segregated as a separate species. It is easily distinguished by its large flowers which are light-colored, and also by the rounded sinuses of the calyx.

Type locality: Lyons, France, where it grew from seeds imported from Chile. *Distribution*: Chile, Paraguay, and Uruguay.

Specimens examined: CHILE: (Bertero 201 and 940; Poeppig, probably the type of *C. popayanensis* [not H. B. K.]); St. Jago (Gay 449); Rancagua (Bertero 205, taken to

represent the type of Choisy's *C. corymbosa*; St. Augustin de Tango (Reed in 1867); Valparaiso (Rusby 2000); Valdivia (Lechler 479); Prov. Santiago (Philippi in 1861 and in 1862).

PARAGUAY: Montevideo (Fruchard).

URUGUAY: Salto (Osten 3324).

29. *Cuscuta racemosa* Martius

Cuscuta racemosa Martius in Spix and Martius, Reise Bras. 1: 286. 1823.—Choisy, Mém. Soc. Phys. Hist. Nat. Genève 9: 277, Pl. 3, fig. 1. 1841; and in De Candolle, Prodr. 9: 456. 1845.

Cuscuta racemosa brasiliensis Engelmann, Trans. Acad. Sci. St. Louis 1: 505. 1859.—Progel in Martius, Flora Brasiliensis 7: 384, Pl. 125. 1871.

Stems slender, smooth or rarely papillate. Flowers 2.5–4 mm. long, more or less glandular, on pedicels mostly about as long as the flowers, in loose, racemose clusters, membranous or somewhat fleshy, straw-colored to deep red; calyx shorter than the tube, or equaling it in one variety; lobes ovate, obtuse or rarely somewhat acutish; corolla campanulate, lobes ovate, obtuse or rarely slightly acutish, tips inflexed or straight; stamens shorter than the lobes, the oval anthers about equal to the stoutish, subulate filaments; scales mostly about reaching the stamens, oblong, copiously fringed particularly about the upper half, bridged below the middle; stigmas ordinarily large and frequently flattened, styles stoutish and not infrequently more or less subulate, equal to, or longer than, the globose or obovate ovary which is thickened at the top. Capsule globose, carrying the withered corolla about it or toward its base; seeds one to four in each capsule, oval, about 2 mm. long, hilum short, perpendicular or oblique.

KEY TO THE VARIETIES

Calyx lobes ordinarily not overlapping, longer than broad, mostly reaching beyond the middle of the corolla tube.

Capsule covered or surrounded by the withered corolla, not becoming markedly exerted.....*typica*.

Capsule becoming exerted and not covered by the withered corolla.....*nuda*.

Calyx lobes commonly more or less overlapping, about as broad as long, ordinarily not reaching the middle of the tube and frequently papillate.....*miniata*.

Cuscuta racemosa typica

(Pl. IV, fig. 23, A–E)

Flowers about 3 mm. long; calyx shorter than the corolla tube, lobes ordinarily not overlapping, longer than broad; corolla lobes shorter than the tube, obtuse, tips commonly inflexed.

Type locality: Province Rio de Janeiro, Brazil. *Distribution:* Central and southern Brazil.

Specimens examined: BRAZIL: (Riedel: Booz; Ule 321; Pohl 5100); Prov. Rio de Janeiro (Graham; Riedel 625; Martius in 1817, taken to represent the type, a fragment in the Engelmann herbarium; Rudol.; Capt. Wilkes; Burchell 2739; Gardner 5535; Martius 911; Gaudichaud 507); Petropolis (Ball in 1882); Prov. Parana (Dusen 4006; 7087, 10005, 11340); Prov. Minas Geraes (Lindberg 107; Hillosen 4484; Gaudichaud 52; St. Hilaire D. 557; Weddell; Caldas (Hochne 2774); Prov. São Paulo (Brade 6026; Glaziov 19677 in part; Gaudichaud 345; Mboi (Gehrt 3351); Prov. Santa Catharina (Ule 1848);

Ilha do Governador, Rio de Janeiro Bay (Miers 3430); Isl. Paqueta, Rio de Janeiro Bay (Rose and Russell 20287); Tropical Brazil (Burchell 6674).

Cuscuta racemosa nuda Engelm.

Cuscuta racemosa nuda Engelm., Trans. Acad. Sci. St. Louis 1: 505. 1859.—Progel in Martius, Flora Brasiliensis 7: 384, Pl. 128, fig. 3. 1871.

? *Cuscuta citricola* Schlechtendal, Linnaea 22: 808. 1849.

Cuscuta racemosa Regnelliana Progel in Martius, Flora Brasiliensis 7: 384. 1871.

Calyx lobes ovate, not overlapping, nearly as long as the corolla tube; corolla lobes reflexed and about equal to the tube. Capsule depressed-globose, exerted, intrastylar aperture large; scales oblong. This variety when not in fruit looks very much like variety *brasiliensis*.

Type locality: "Near Rio, Brazil." *Distribution*: Southern Brazil.

Specimens examined: BRAZIL: (Sellow, taken to represent the type, a fragment in the Engelm. herbarium); Prov. Minas Geraes (Regnell III 308; two collections of this number were examined, one collected Dec. 26, 1864, and the other Feb. 7, 1866. This is the type number of variety *Regnelliana*; Widgren in 1845).

Cuscuta racemosa miniata Engelm.

(Pl. IV, fig. 23, F)

Cuscuta racemosa miniata Engelm., Trans. Acad. Sci. St. Louis 1: 505. 1859.—Progel in Martius, Flora Brasiliensis 7: 384. 1871.

Cuscuta miniata Martius in Spix and Martius, Reise Bras. 1: 286. 1823.

Cuscuta racemosa miniata Choisy, Mém. Soc. Phys. Hist. Nat. Genéve 9: 277. 1841; and in De Candolle, Prodr. 9: 456. 1845.

Cuscuta tenuiculis Glaziov, Mém. Soc. Bot. France 3: 491. 1911.

Stems smooth or frequently papillate, the papillations extending part way on to the calyx in some specimens; calyx very short, the lobes commonly broader than long, overlapping; flowers fleshier in texture than those of the other varieties, and reddish.

Type locality: Brazil. *Distribution*: Central and southern Brazil.

Specimens examined: BRAZIL: (Martius 1292, taken to represent the type, a fragment in the Engelm. herbarium); Ackermann in 1832; Prov. Minas Geraes (Vauthier 252; Schwacke 8208; Glaziov 10676, the type number of *C. tenuiculis*; St. Hilaire B 2083; Langsdorff; Prov. São Paulo (St. Hilaire C 1488; Prov. Goyaz (Glaziov 20422; Prov. Matto Grosso, Cuiabá (Riedel 870 in part, mixed with *C. parviflora*).

30. *Cuscuta platyloba* Progel

(Pl. V, fig. 27, A E)

Cuscuta platyloba Progel in Martius, Flora Brasiliensis 7: 381, Pl. 127, fig. 3. 1871.

Cuscuta racemosa calycina Engelm., Trans. Acad. Sci. St. Louis 1: 505. 1859.

Stems slender. Flowers 2-4 mm. long, on pedicels shorter than the flowers, in few- to many-flowered paniculate or racemose cymes; calyx about equal to the corolla tube; lobes ovate, obtuse, overlapping, entire or irregular, sometimes slightly carinate; corolla campanulate, lobes ovate, obtuse, overlapping, about equal to the tube, upright or becoming reflexed; stamens shorter than the lobes, anthers oval, about equal to, or shorter

than, the subulate filaments; scales reaching the stamens, ovate, fringed with moderate processes, bridged at about the middle or somewhat below; ovary globose, styles slender and shorter than, or becoming longer than, the ovary, stigmas medium or infrequently large and convoluted. Capsule globose, with the withered corolla about it; styles becoming stoutish and sometimes slightly subulate, not circumsissile, thin towards the base; seeds two to four in each capsule, about 1.5 mm. long; hilum oblong, oblique.

It is believed that what Progel described as *C. platyloba* is a smaller form of Engelmann's *C. racemosa calycina*. The specimens here considered closely approach *C. racemosa*, but it is believed that they show characters that will allow of their being maintained as a distinct species.

Type locality: "Montevideo." *Distribution*: Southern Brazil and Uruguay.

Specimens examined: BRAZIL: Prov. Goyaz (Glaziov 21808); Prov. Rio de Janeiro (Ule 3565; Glaziov 11279; Hillosen 2538); Prov. Santa Catharina (Pabst 89); Central Brazil (Weddell 2124, probably the type of *C. racemosa calycina*); southern Brazil (Sellow); Minas, Serra da Piedade (Hoehe 6187).

URUGUAY: Montevideo (Sellow 30, taken to represent the type, in the U. S. National Herbarium; Fruchard in 1874 and in 1875).

31. *Cuscuta stenolepis* Engelmann

(Pl. V, fig. 31. A-E)

Cuscuta stenolepis Engelmann, Trans. Acad. Sci. St. Louis 1: 503. 1859.

Stems slender, densely matted. Flowers few and scattering, about 2.5 mm. long, on pedicels as long as, or shorter than, the yellowish or infrequently reddish, glandular flowers, in scattered, few-flowered, paniculate or cymose clusters; calyx deeply divided, reaching the middle of the corolla tube or nearly to the sinuses in some flowers, lobes ovate, obtuse; corolla subcylindrical, lobes about half as long as the tube, oblong-ovate, obtuse, reflexed, with inflexed tips; stamens shorter than the lobes, filaments equal to, or shorter than, the oval anthers; scales about reaching the stamens, bridged at a third or a quarter of their height, narrow, sparingly fringed with a few scattered processes; styles slender, about equal to the globose, apiculate ovary. Capsule globose or conic, with the withered corolla about the apex like a hood; seeds subglobose, about 1.5 mm. long.

Type locality: Andes of Quito, Ecuador. *Distribution*: Known only from Ecuador.

Specimens examined: ECUADOR: Quito (Hall, the type, a fragment in the Engelmann herbarium; Couthouy: E. W. D. and Mary M. Holway Aug. 21, 1920); Otavalo (Holmgren 908).

32. *Cuscuta parviflora* Engelmann

Cuscuta parviflora Engelmann, Trans. Acad. Sci. St. Louis 1: 506. 1859.—Progel in Martius, Flora Brasiliensis 7: 385, Pl. 128, fig. 5. 1871. Not Nuttall nor Willdenow. *Cuscuta micrantha* Martius in herb., ex Engelmann, Trans. Acad. Sci. St. Louis 1: 506. 1859. Not Choisy.

Stems slender, matted. Flowers 1-2 mm. long, on pedicels mostly much

longer than the flowers, in loose, few-flowered, cymose clusters; calyx shorter than, or about equaling, the corolla tube; lobes ovate to triangular-ovate, obtuse or slightly acutish, slightly, if at all, overlapping; corolla widely campanulate, lobes longer than the tube, spreading or upright with inflexed tips, ovate or lanceolate, obtuse to acute; stamens shorter than the lobes or rarely longer than the lobes; oval anthers about equal to, or shorter than, the slender filaments; scales reaching the stamens, ovate, fimbriate, bridged below the middle; styles about equal to the globose ovary; capsules depressed-globose, much larger than the flower, exerted, withered corolla persistent at the base, intrastylar aperture large, not circumscissile; seeds 1-1.25 mm. long, globose, hilum oblong, perpendicular.

This is the smallest of the species seen from South America and seems to produce capsules sparingly. Only two or three mature fruits were seen in the several specimens examined.

Cuscuta parviflora typica

(Pl. V, fig. 25, A-E)

Flowers 1.5-2 mm. long. Corolla lobes ovate, obtuse or only slightly acutish, stamens shorter than the corolla lobes.

Type locality: Villa Rica, Brazil. *Distribution:* Southern Brazil.

Specimens examined: BRAZIL: (St. Hilaire): Villa Rica (Pohl 5726, taken to represent the type of this, a fragment in the Engelmann herbarium); Prov. Minas Geraes, Ouro Preto (Schwacke 7560; Ule 2652; E. W. D. and Mary M. Holway 1374).

Cuscuta parviflora elongata Engelm.

(Pl. V, fig. 25, F)

Cuscuta parviflora elongata Engelm., Trans. Acad. Sci. St. Louis 1: 506. 1859.—Progel in Martius, Flora Brasiliensis 7: 386. 1871.

Flowers 1-1.5 mm. long. Calyx lobes acutish; corolla lobes triangular or lanceolate, acute, stamens equal to or exceeding the corolla lobes.

Type locality: Minas Geraes, Brazil (?). *Distribution:* Central and southern Brazil.

Specimens examined: BRAZIL: Goyaz (Weddell 2125); São Paulo (St. Hilaire C 665)

33. *Cuscuta cristata* Engelm.

(Pl. V, fig. 28, A-E)

Cuscuta cristata Engelm., Trans. Acad. Sci. St. Louis 1: 507. 1859.

Stems medium. Flowers 2.5-3 mm. long, slightly fleshy and glandular, subsessile on short, stout pedicels in few- to many-flowered, lateral, cymose clusters, perianth segments frequently uneven; calyx as long as the corolla tube; lobes broadly ovate, obtuse, frequently with an uneven, cristate carina which may extend down on to the pedicel, overlapping; corolla widely campanulate, early becoming somewhat globular about the developing capsule; lobes slightly shorter than the tube, ovate, obtuse, spreading, becoming reflexed in fruit; stamens shorter than the lobes, the oval anthers

about equal to the stout, subulate filaments; scales reaching the stamens or shorter, bridged below the middle, slightly spatulate, sparingly fringed with medium-length processes, particularly about the upper half; styles stoutish, much shorter than the large, globose ovary which is thickened at the top, stigmas very small. Capsule depressed-globose, thin towards the base where it may break away when pulled, carrying the withered corolla about it or toward the base, styles becoming divaricate, intrastylar aperture large and rhomboid; seeds about 1.5 mm. long, oblique, rostrate.

This species is distinguished mainly by the shape of its capsule and the size of the stigmas.

Type locality: "Province of St. Jago de Tucuman, La Plata," Argentina.

Distribution: Central Argentina.

Specimens examined: ARGENTINA: La Plata (Tweedie 1191, the type, a fragment in the Engelmann herbarium); Buenos Aires (Beltfreund and Koester 342); Cordoba (Gallander; Lorentz 90); Parana (Gilbert 78); Prov. La Rioja (Hieronymus and Niederlein 745, 846).

34. *Cuscuta indecora* Choisy

For the synonymy and description of this species and its varieties see Yuncker, Ill. Biol. Monogr. 6: 147. 1921; also Progel in Martius, Flora Brasiliensis 7: 382, Pl. 127, fig. 6. 1871.

KEY TO THE VARIETIES

Scales ovate, prominently fringed.

Calyx lobes orate, obtuse or acutish, not exceeding the corolla.

Styles as long as the ovary, not divaricate.

Flowers 2-3 mm. long, papillose-hispid (no specimens of this have been seen from South America)..... *hispidula*.

Flowers usually larger, not papillose-hispid..... *neuropetala*.

Styles short, becoming divaricate in fruit..... *subnuda*.

Calyx lobes lanceolate, acute, usually exceeding the corolla..... *longisepala*.

Scales triangular, shallowly fringed..... *integriscula*.

Scales bifid, rudimentary..... *bifida*.

Cuscuta indecora neuropetala (Choisy) Hitchcock

Distribution in South America: Venezuela, Brazil, and Paraguay.

Specimens examined: BRAZIL: Maranhão (Gardner 6068 in part).

PARAGUAY: Asunción (Lindman A 2325).

VENEZUELA: Ciudad Bolívar (L. H. and Ethel Zoe Bailey 12355).

Cuscuta indecora subnuda Engelm.

Cuscuta indecora subnuda Engelm., Trans. Acad. Sci. St. Louis 1: 502. 1859.

Engelm. characterizes this variety as having an exerted capsule and short, divaricate styles. I did not see the type specimen nor any other that would seem to belong here. It is apparently a rare form.

Cuscuta indecora longisepala Yuncker

Distribution in South America: Through central part of the continent.

Specimens examined: BOLIVIA: Gran Chaco (Fries 1629).

PARAGUAY: (Balansa 2062; Morong 250).

PERU: Piura (Spruce); Pacasmayo (Mr. and Mrs. J. N. Rose 18517).

Cuscuta indecora integriscala Engelm.

Cuscuta indecora integriscala Engelm., Trans. Acad. Sci. St. Louis 1: 502. 1859.

Scales shallowly fringed, triangular, reaching the stamens, bridged at about the middle; styles very slender, shorter than the ovary; calyx lobes triangular, acute, and about equal to the corolla tube.

Type locality: Mendoza, Argentina. *Distribution:* Known only from the type locality.

Specimens examined: ARGENTINA: Mendoza (Gillies, the type, a fragment in the Engelm. herbarium).

Cuscuta indecora bifida Yuncker

Distribution in South America: Brazil.

Specimen examined: BRAZIL: Minas Geraes (Gardner 5036. This specimen has lanceolate calyx lobes characteristic of variety *longisepala* and the bifid scales of this).

35. *Cuscuta globosa* Ridley

(Pl. V, fig. 26, A-E)

Cuscuta globosa Ridley, Journ. Linn. Soc. 27: 48. 1890.

Stems slender. Flowers 1.5-2 mm. long, on pedicels mostly exceeding the length of the flowers; calyx about as deep as the corolla, lobes triangular, acute, frequently unequal; corolla campanulate; lobes triangular, acute, upright, about equal to the tube; stamens about equaling the lobes, slenderly subulate filaments much longer than the oval anthers; scales reaching the stamens, ovate, moderately fringed with short processes, bridged below the middle; styles longer than the globose ovary. Capsule depressed-globose, thin, not circumscissile; seeds commonly two in each capsule, about 1-1.25 mm. long, subglobose, flattened on one side, hilum small, withered corolla about the capsule towards its base, the capsule much exerted.

This species seems to be closely related to both *C. acuta* and *C. micrantha*, but differs from both of these species in the possession of pedicels mostly longer than the flowers, in its smaller flowers, and longer stamens. Also, the withered corolla is retained towards the base of the capsule.

Type locality: Island of Fernando de Noronha, Brazil. *Distribution:* Known only from the type locality.

Specimens examined: BRAZIL: Fernando de Noronha, summit of Morro Branco, and near Tangle Bay (Ridley, Lea, and Ramage 72, taken to represent the type, in the Royal Botanical Museum, Kew).

36. *Cuscuta micrantha* Choisy

Cuscuta micrantha Choisy, Mém. Soc. Phys. Hist. Nat. Genève 9: 271, Pl. 1, fig. 3. 1841;
and in De Candolle, Prodrômus 9: 453. 1845.—Gay, Fl. Chile 4: 446. 1849.—
Engelmann, Trans. Acad. Sci. St. Louis 1: 500. 1859.—Reiche, Fl. Chile 5: 171.
1910.

Cuscuta popayanensis Poeppig, ex Engelmann, Trans. Acad. Sci. St. Louis 1: 500. 1859.
? *Cuscuta pauciflora* Philippi, Linnæa 33: 185. 1864.

Cuscuta sparsiflora Philippi in sched. ex Reiche, Fl. Chile 5: 171. 1910.

Stems slender. Flowers about 2–3 mm. long, on pedicels shorter than the flowers in rather dense, compact clusters, or looser in the second variety; calyx about as long as the corolla tube; lobes ovate, acute; corolla campanulate, lobes ovate, acute, upright or slightly spreading, shorter than, or (in the second variety) about equaling, the tube; scales narrow, oblong, quite firmly attached for nearly their whole length, sparingly fringed about the top with few processes, bridged at about a quarter of their height, or the scales larger and more prominently fringed and with the bridges somewhat higher, about reaching the stamens; stamens shorter than the lobes, filaments shorter than or exceeding the length of the ovate-cordate to oval anthers, slender or slightly subulate; styles slender and shorter than, or about equal to, the ovoid ovary. Capsule ovoid, or globose and somewhat depressed, hilum small, about 1 mm. long.

Cuscuta micrantha typica

(Pl. I, fig. 2, A–E)

Flower clusters small, compact; corolla lobes shorter than the tube, scales narrow, sparingly fringed about the upper portion only, flowers about 2 mm. long, anthers small, ovate-cordate, ovary and capsule ovoid, stigmas small.

Type locality: Prov. Coquimbo, Chile. *Distribution:* Central Chile.

Specimens examined: CHILE: Prov. Coquimbo (Gay 538, the type, a fragment in the Engelmann herbarium); Santiago (Philippi; Reiche III–99); Cerro Blanco (Hastings 154. This specimen shows characters of this and also of the next variety).

Cuscuta micrantha latiflora Engelmann

(Pl. I, fig. 2, F, G)

Cuscuta micrantha latiflora Engelmann, Trans. Acad. Sci. St. Louis 1: 500. 1859.—Gay, Fl. Chile 4: 446. 1849.

Cuscuta pusilla Philippi, in herb.

Flowers 2.5–3 mm. long, corolla lobes about equal to the tube, anthers oval and larger than in the preceding variety; scales larger and more prominently fringed. Capsule globose and somewhat depressed, three- or four-seeded.

Type locality: Concon, Chile. *Distribution:* Chile.

Specimens examined: CHILE: (v. Better 142; this specimen approaches the typica variety; Reed); Concon (Poeppig, taken to represent the type, a fragment in the Engelmann herbarium); Valparaíso (Brenning 91); Panamavida, Linares (E. W. D. and Mary M. Holway Dec. 17, 1919); Desert of Atacama (Morong 1103); Sans Jago (Hohenacker 489).

37. *Cuscuta acuta* Engelm.

(Pl. II, fig. 8, A-E)

Cuscuta acuta Engelm., Trans. Acad. Sci. St. Louis 1: 497. 1859.

Stems slender. Flowers 2-3 mm. long, on pedicels about as long as the flowers, thin and membranous, in umbellate clusters; calyx campanulate, lobes triangular-ovate, acute to acuminate or somewhat cuspidate, or obtusish, as long as, or exceeding, the corolla tube; corolla campanulate, lobes lanceolate, acute to acuminate, upright or somewhat spreading in fruit, as long as, or longer than, the tube, stamens about three fourths as long as the corolla lobes; filaments stout, subulate, about equal in length to, or much longer than, the oval anthers; scales reaching the stamens, thin, bridged below the middle, closely adherent to the tube, fringed about the upper half; styles about equal to the globose ovary, slightly subulate. Capsule not circumscissile though very easily breaking away at the base, carrying the withered corolla about it, very thin and almost transparent in some specimens so that the seeds are visible in it, depressed-globose, intrastylar aperture comparatively large, styles upright or more often becoming divergent; seeds about 1 mm. long, ovate, hilum short, oblong.

This species differs from *C. pentagona*, which it resembles somewhat, in the shapes of the filaments, calyx and corolla lobes, and the divergent styles.

Type locality: "Chatham Island of the Galapagos group." *Distribution*: Galapagos Islands.

Specimens examined: GALAPAGOS ISLANDS: Chatham Island (Andersson, the type, a fragment in the Engelm. herbarium); South Marborough Island (Snodgrass and Heller 318); Birdloe Island (Snodgrass and Heller 769).

38. *Cuscuta insquamata* n. sp.

(Pl. V, fig. 30, A-D)

Stems slender. Flowers 1.5-2 mm. long, delicate, 4- or 5-parted, on pedicels shorter than or longer than the flowers in dense cymose clusters, membranous with a few scattering yellow, pellucid glands; calyx longer than the corolla tube, lobes triangular, acuminate; corolla shallowly campanulate, lobes upright, triangular, acuminate, about as long as the tube; stamens shorter than the lobes, ovate anthers about equal to the stout, subulate filaments; scales lacking; slender styles shorter than, or equaling, the globose, somewhat pointed ovary, which is thickened at the apex. Capsule carrying the corolla about it towards the base, depressed-globose, with a fleshy collar about the intrastylar aperture, evidently not circumscissile although a few capsules seemed to have a weaker zone towards the base where they break loose when pulled; seeds four in each capsule, roundish, hilum small.

Type locality: Bolivia. *Distribution*: Known only from the type locality.

Specimens examined: BOLIVIA: (Fiebrig 3045, the type, in the Museum of Natural History, Asunción, Paraguay, a fragment in the author's herbarium).

INDEX OF COLLECTIONS

- ACKERMAN
(1832). *C. racemosa miniata*
- ANDERSSON
(1852). *C. chilensis*
—, *C. acula*
- ANISITS
462. *C. xanthochortus lanceolata*
2395; 2555; 2854. *C. incurvata*
- BAILEY AND BAILEY
1255. *C. indecora neuropetala*
- BALANSA
2062. *C. indecora longisepala*
2064; 2066. *C. xanthochortus lanceolata*
- BALL
(1882). *C. racemosa typica*
(1882). *C. chilensis*
- BANG
115 in part. *C. grandiflora*
115 in part; 1304. *C. globiflora*
1303. *C. odorata typica*
- BAUR
205. *C. gymnocarpa*
- BELTFREUND AND KOESTER
342. *C. cristata*
- BERTERO
201 and 946; 205. *C. suaveolens*
- V. BETTER
142. *C. micrantha latiflora*
- BIRSCHER
—, *C. corymbosa grandiflora*
- BLANCHET
736. *C. americana congesta*
3047. *C. partita*
- BOOZ
—, *C. racemosa typica*
- BRADÉ
6026. *C. racemosa typica*
- BRENNING
91. *C. micrantha latiflora*
- BUCHLIEN
113; 133; 753; 3235; 4504. *C. globiflora*
460; 752; 2946; 4501; (1912). *C. grandiflora*
1157; 4502; 4503; 4507; (1903). *C. chilensis*
- BURCHELL
667A; 2739. *C. racemosa typica*
- CLAREN
11692. *C. odorata Hulseana*
- CLAUSSEN
306. *C. americana congesta*
- COURBON
146. *C. pentagona typica*
- COUTHOUY
(1855). *C. foetida typica*
—, *C. stenolepis*
- CUMING
350. *C. chilensis*
- DUSÉN
3006; 7987; 10005; 11349. *C. racemosa typica*
- EDMONSTON
—, *C. grandiflora*
—, *C. chilensis*
- FENDLER
946. *C. corymbosa grandiflora*
2069. *C. americana congesta*
- FIERRIG
487. *C. trichostyla carinata*
2523. *C. boliviana*
3045. *C. insignumata*
4254; 5083; (1909). *C. incurvata*
6705; —, *C. xanthochortus lanceolata*
- FRIES
229. *C. americana spectabilis*
906. *C. microstyla*
1287. *C. grandiflora*
1629. *C. indecora longisepala*
- FRUCHARD
(1874; 1875). *C. platylola*
(1871; 1875). *C. pentagona typica*
—, *C. suaveolens*
- GALANDER
—, *C. cristata*
- GARDNER
1775. *C. americana congesta*
2425. *C. umbellata typica*
2684; 2689. *C. partita*
3348. *C. bracteata*
5036. *C. indecora bifida*
5555. *C. racemosa typica*
6068 in part. *C. pentagona subulata*
6068 in part. *C. indecora neuropetala*
- GAUDICHAUD
52; 345; 507. *C. racemosa typica*
- GAY
38. *C. odorata typica*
449. *C. suaveolens*
538. *C. micrantha typica*
817; —, *C. chilensis*
2168. *C. odorata typica*
—, *C. grandiflora*

- GEHRT
 3351. *C. racemosa typica*
 GILBERT
 78. *C. cristata*
 GILLIES
 ———, *C. chilensis*
 ———, *C. indecora integruscula*
 GLAZIOU
 11279; 21808. *C. platyloba*
 19676; 20422. *C. racemosa miniata*
 19677 in part. *C. pentagona subulata*
 19677 in part. *C. racemosa typica*
 21809. *C. orbiculata*
 21810. *C. goyaziana*
 21811; 21811 $\frac{1}{2}$. *C. serrata*
 GOLLNER
 ———, *C. corymbosa grandiflora*
 GOLDOF
 ———, *C. grandiflora*
 GRAHAM
 ———, *C. racemosa typica*
 HALL
 ———, *C. stenolepis*
 HARTWEG
 1237. *C. corymbosa grandiflora*
 1238. *C. foetida pycnantha*
 HARVEY
 (1856). *C. chilensis*
 HASSLER
 3918. *C. obtusiflora*
 4604; 5113. *C. xanthochortus lanceolata*
 8178. *C. incurvata*
 HASTINGS
 146; 291; 395. *C. chilensis*
 154. *C. micrantha typica*
 HIERONYMUS
 (1883). *C. brevisquamata*
 HIERONYMUS AND LORENTZ
 124. *C. grandiflora*
 HIERONYMUS AND NIEDERLEIN
 745; 846. *C. cristata*
 HILLOSEN
 2538. *C. platyloba*
 4484. *C. racemosa typica*
 HITCHCOCK
 16564. *C. umbellata typica*
 HOEHNE
 1048; 4483. *C. partita*
 2774. *C. racemosa typica*
 4016. *C. luisiflora*
 6187. *C. platyloba*
 HOHENACKER
 489. *C. micrantha latiflora*
 HOLMGREN
 442. *C. foetida typica*
 594. *C. grandiflora*
 908. *C. stenolepis*
 924. *C. corymbosa grandiflora*
 HOLTON
 543. *C. grandiflora*
 HOLWAY AND HOLWAY
 1374. *C. parviflora typica*
 (1919). *C. micrantha latiflora*
 (1919; 1920). *C. chilensis*
 (1920). *C. grandiflora*
 (1920). *C. foetida typica*
 (1920). *C. odorata typica*
 (1920). *C. odorata Holwayana*
 (1920). *C. stenolepis*
 (1920). *C. globiflora*
 HUMBOLDT
 ———, *C. grandiflora*
 ———, *C. foetida typica*
 ———, *C. corymbosa grandiflora*
 ———, *C. obtusiflora*
 HUSBANDS
 1015. *C. chilensis*
 JAMISON
 542. *C. pentagona subulata*
 (1864). *C. foetida typica*
 JENMAN
 6098. *C. umbellata typica*
 JOANNES DE SANTA BARBARA, FATHER
 ———, *C. xanthochortus typica*
 JORGENSEN
 1160. *C. argentiniana*
 1420. *C. grandiflora*
 1702. *C. globiflora*
 KARSTEN
 ———, *C. corniculata*
 ———, *C. americana congesta*
 KUNZE
 (1892). *C. chilensis*
 LANGSDORFF
 ———, *C. racemosa miniata*
 LUDLER
 479. *C. suaveolens*
 1501. *C. chilensis*
 LEE
 (1888). *C. chilensis*
 LINDBERGH
 167. *C. racemosa typica*
 LINDMAN
 A2325. *C. indecora neuropetala*
 A3481. *C. partita*

- LOBB
 49. *C. odorata botryoides*
 LORENTZ
 64. *C. obtusiflora*
 90. *C. cristata*
 214. *C. chilensis*
 MALME
 1002; 1416. *C. xanthochortus typica*
 1898. *C. americana congesta*
 MANDON
 1479; 1499. *C. grandiflora*
 1480 in part. *C. odorata typica*
 1480 in part. *C. globiflora*
 1481. *C. acutiloba*
 MARTINET
 1027; ——. *C. odorata typica*
 ——. *C. chilensis*
 MARTIUS
 941; (1817). *C. racemosa typica*
 1292. *C. racemosa miniata*
 ——. *C. umbellata typica*
 MATTHEW
 486. *C. odorata typica*
 MATTHEWS
 (1857). *C. acutiloba*
 MAYOR
 239. *C. americana congesta*
 MAXIMOWICZ
 ——. *C. chilensis*
 MERKENS
 ——. *C. chilensis*
 MIERS
 3430. *C. racemosa typica*
 MORONG
 259. *C. indecora longisepala*
 1143. *C. chilensis*
 1163. *C. micrantha latiflora*
 MOSELEY
 (1873). *C. orbiculata*
 (1873). *C. americana congesta*
 NATION
 (1862). *C. odorata typica*
 NIEDERLEIN
 1308. *C. xanthochortus typica*
 OSTEN
 33. *C. epithymum*
 3324. *C. suaveolens*
 PABST
 89. *C. platyloba*
 565. *C. pentagona subulata*
 PACHANO
 140. *C. grandiflora*
 PAGE
 (1854). *C. xanthochortus lanceolata*
 PAVON
 ——. *C. prismatica*
 PAVON HERB.
 ——. *C. odorata typica*
 ——. *C. corymbosa microlepis*
 PENNELL
 1453. *C. corniculata*
 PENTLAND
 ——. *C. globiflora*
 PFLANZ
 40; 454. *C. grandiflora*
 382. *C. globiflora*
 PHILIPPI
 656; (1888). *C. chilensis*
 (1861; 1862). *C. suaveolens*
 ——. *C. micrantha typica*
 PITTIER
 6404. *C. partita*
 POEPPIG
 ——. *C. suaveolens*
 ——. *C. chilensis*
 ——. *C. micrantha latiflora*
 POHL
 5100. *C. racemosa typica*
 5726. *C. parviflora typica*
 REED
 (1867). *C. suaveolens*
 ——. *C. micrantha latiflora*
 REGNEL
 III 308. *C. racemosa nuda*
 REICHE
 III 99. *C. micrantha typica*
 REIDEL
 695; ——. *C. racemosa typica*
 846. *C. partita*, in part
 846. *C. racemosa miniata*, in part
 REMY
 (1856). *C. prismatica*
 ——. *C. corymbosa grandiflora*
 REYNOLDS
 95. *C. microstylis*
 RIDLEY, LEE, AND RAMAGE
 72. *C. globosa*
 73. *C. americana congesta*
 RODWAY
 ——. *C. umbellata typica*
 ROSE, PACHANO, AND ROSE
 23272. *C. odorata typica*
 ROSE AND ROSE
 18517. *C. indecora longisepala*
 22256. *C. odorata typica*
 ROSE AND RUSSELL
 20287. *C. racemosa typica*

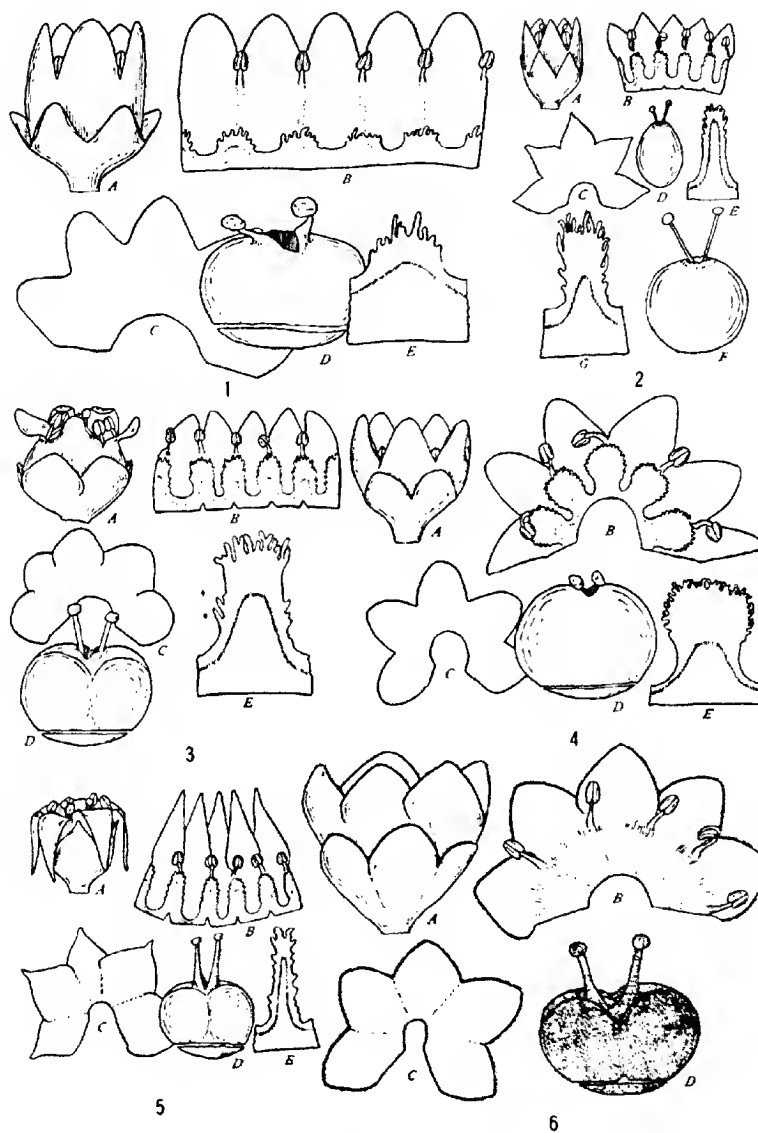
- RUDIO
—, *C. racemosa typica*
- RUIZ HERD.
—, *C. odorata typica*
—, *C. corymbosa microlepis*
- RUSBY
2000. *C. suaveolens*
2001. *C. chilensis*
2002; 2003. *C. grandiflora*
2004. *C. globiflora*
- RUSBY AND PENNELL
93. *C. americana congesta*
- ST. HILAIRE
D482. *C. odorata typica*
D557. *C. racemosa typica*
C1665. *C. parviflora elongata*
C1711. *C. serrata*
C1271. *C. pentagona subulata*
C1488; B12085. *C. racemosa miniata*
—, *C. parviflora typica*
- SALZMAN
(1845). *C. americana congesta*
- SAVATIER
460; 1362. *C. odorata typica*
1751. *C. chilensis*
- SCHWACKE
7560. *C. parviflora typica*
8208. *C. racemosa miniata*
- SEEMAN
30; —, *C. foetida typica*
852. *C. odorata typica*
- SELLOW
30; *C. platyloba*
2489. *C. xanthochortus typica*
—, *C. chilensis*
—, *C. platyloba*
- SMITH
1590; 2549. *C. americana congesta*
(1890-91). *C. chilensis*
- SODIRO
1139. *C. americana congesta*
- SPRUCE
854. *C. trichostyla typica*
5017. *C. foetida typica*
—, *C. indecora longispala*
- STEWART
3092. *C. gymnocarpa*
- SNODGRASS AND HELLER
318; 769. *C. acuta*
- TRIANA
2178; (1851-57); —, *C. obtusiflora*
(1851-57). *C. grandiflora*
(1851-57). *C. corniculata*
- TWEEDIE
1191. *C. cristata*
—, *C. trichostyla typica*
- ULR.
321; 1848. *C. racemosa typica*
487. *C. pentagona calycina*
2652. *C. parviflora typica*
3009. *C. serrata*
3565. *C. platyloba*
- VAUTHIER
252. *C. racemosa miniata*
- VENTURI
100. *C. pentagona typica*
- WEDDELL
78; 2124. *C. platyloba*
2125. *C. parviflora elongata*
2208; 2298. *C. americana congesta*
3453; 3611. *C. parviflora*
4518; 4768. *C. grandiflora*
4613. *C. odorata typica*
—, *C. racemosa typica*
- WILGREN
1945. *C. racemosa nuda*
- WILKES
—, *C. chilensis*
—, *C. odorata typica*
—, *C. racemosa typica*
- WILLIAMS
2396; 2490. *C. grandiflora*

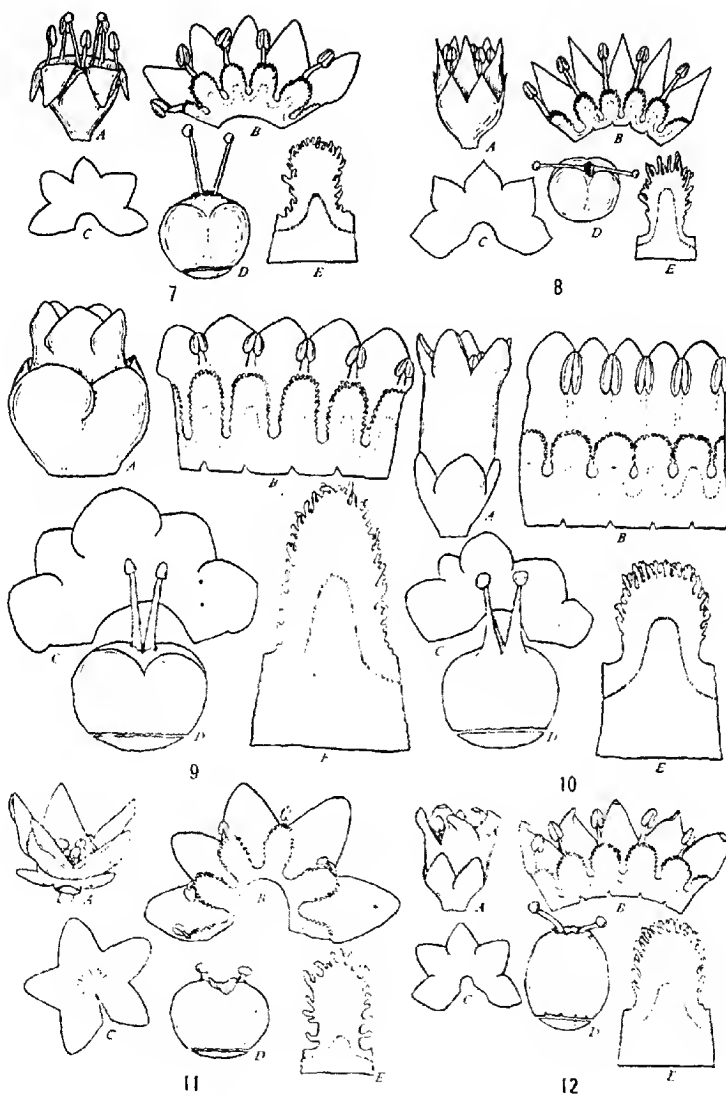
EXPLANATION OF PLATES

All figures are $\times 5$ except those representing the individual scales which are $\times 10$.

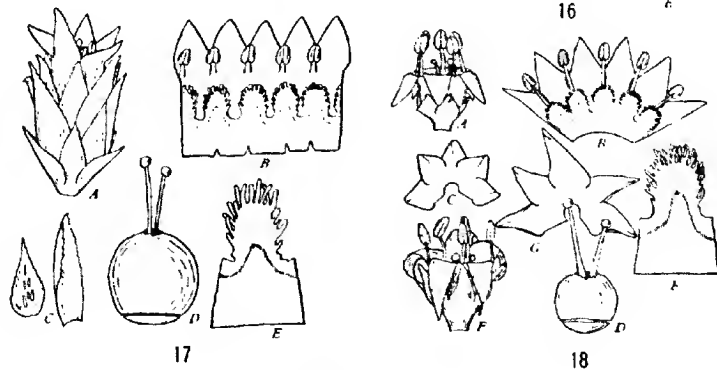
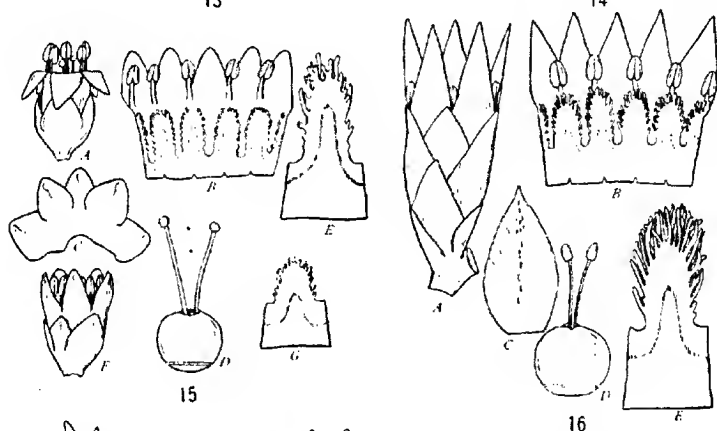
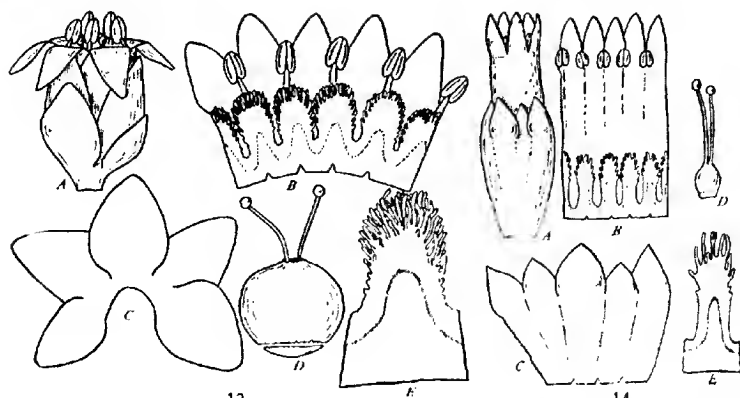
PLATE I

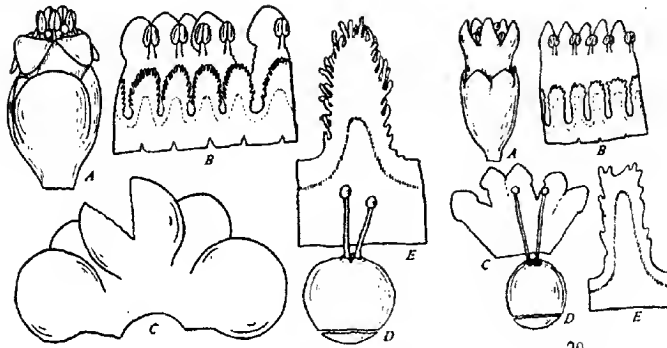
- FIG. 1, A-E. *Cuscuta brevis guianata*, the type collection.
FIG. 2. *Cuscuta micrantha* (A-D), var. *typica*, the type collection; F, G, var. *latiflora*.
FIG. 3, A-E. *Cuscuta boottiana*, the type collection.
FIG. 4, A-E. *Cuscuta microstyla* (Fries 906).
FIG. 5, A-D. *Cuscuta acutiloba*.
FIG. 6, A-D. *Cuscuta grandiflora*.





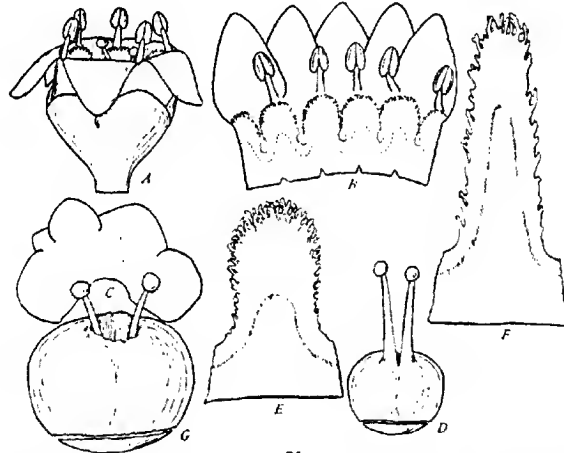
YUNCKER: SOUTH AMERICAN SPECIES OF *CUSCUTA*



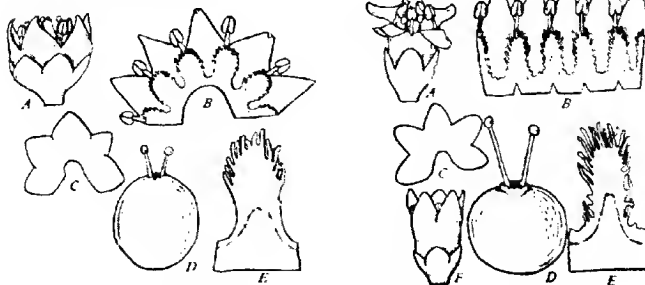


19

20

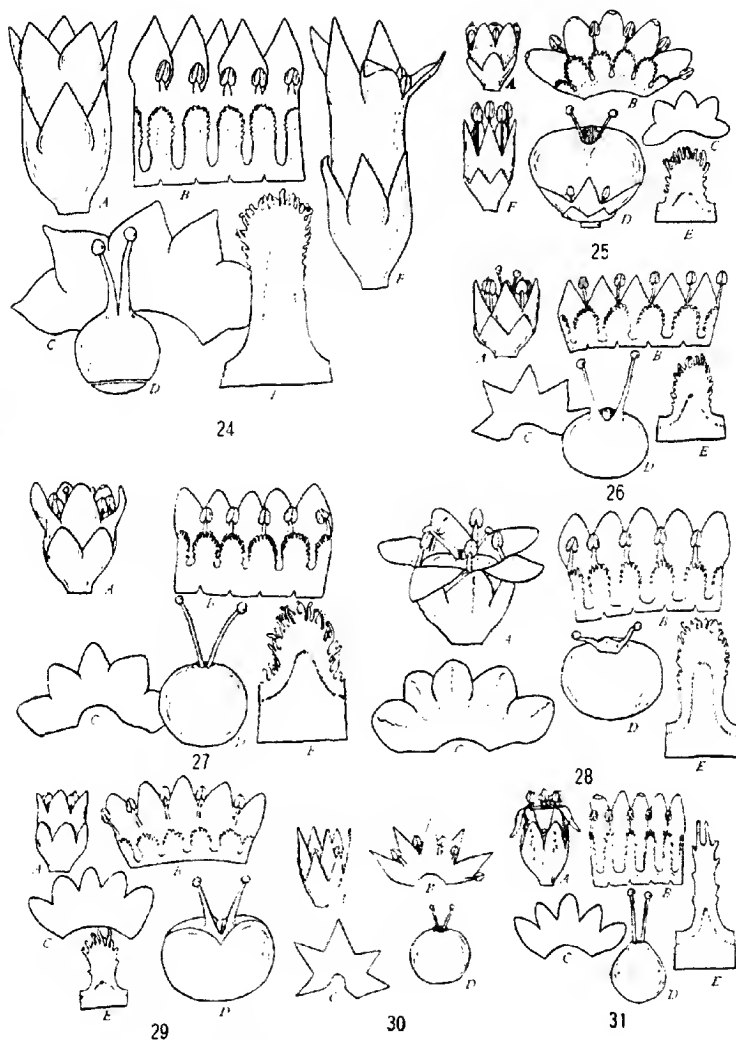


21



22

23



YUSCKER: SOUTH AMERICAN SPECIES OF *CUSCUTA*

PLATE II

- FIG. 7, A-E. *Cuscuta incurvata*.
FIG. 8, A-E. *Cuscuta acuta*, the type collection.
FIG. 9, A-E. *Cuscuta globiflora*.
FIG. 10, A-E. *Cuscuta chilensis*.
FIG. 11, A-E. *Cuscuta argentinana*, the type collection.
FIG. 12, A-E. *Cuscuta corniculata*.

PLATE III

- FIG. 13, A-E. *Cuscuta goyaziana*, the type collection.
FIG. 14, A-E. *Cuscuta prismatica*, the type collection.
FIG. 15. *Cuscuta trichostyla*: A-E, var. *typica*, the type collection; F, G, var. *carinata*, the type collection.
FIG. 16, A-E. *Cuscuta bracteata*, the type collection.
FIG. 17, A-E. *Cuscuta serrata*, the type collection.
FIG. 18. *Cuscuta xanthochortus*: A-E, var. *typica*; F, G, var. *lanceolata*, the type collection.

PLATE IV

- FIG. 19, A-E. *Cuscuta orbiculata*, the type collection.
FIG. 20, A-E. *Cuscuta corymbosa microlepis*, the type collection.
FIG. 21. *Cuscuta odorata*: A-E, var. *typica*; F, var. *Holwayana*, the type collection; G, var. *botryoides*, the type collection.
FIG. 22, A-E. *Cuscuta gymnocarpa*.
FIG. 23. *Cuscuta racemosa*: A-E, var. *typica*; F, var. *miniata*.

PLATE V

- FIG. 24. *Cuscuta foetida*: A-E, var. *typica*; F, var. *pycnantha*, the type collection.
FIG. 25. *Cuscuta parviflora*: A-E, var. *typica*; F, var. *elongata*.
FIG. 26, A-E. *Cuscuta globosa*, the type collection.
FIG. 27, A-E. *Cuscuta platyloba*.
FIG. 28, A-E. *Cuscuta cristata*.
FIG. 29, A-E. *Cuscuta obtusiflora*, the type collection.
FIG. 30, A-E. *Cuscuta insquamata*, the type collection.
FIG. 31, A-E. *Cuscuta stenolepis*, the type collection.

A COMPARATIVE STUDY OF SAND AND SOLUTION CULTURES OF MARQUIS WHEAT

A. L. BAKKE AND L. W. ERDMAN

(Received for publication March 27, 1922)

The present study, in which a comparison is made of the growth of Marquis wheat in sand and solution cultures, represents one of several experiments involving solution III of the National Research Council series which are now in progress in the plant-physiology laboratory at Iowa State College.

Most investigators attempting to determine the salt requirements of higher plants have used water cultures. Tottingham (25) placed the whole proposition on a definite quantitative basis. He took the well-known Knop's solution, and, by varying the proportions of salts under definite volume-molecular partial concentrations, procured a superior yield of wheat of 11 percent over the original solution.

Shive (19) followed the plan suggested by Tottingham¹ and, making use of a three-salt solution containing mono-potassium phosphate, calcium nitrate, and magnesium sulphate, obtained an increase in yield of wheat of 27 percent over Tottingham's solution of the same total concentration. McCall (10) used Shive's solution and grew wheat in sand cultures. He noted that the average dry weights of both tops and roots were decidedly greater for the plants grown in sand than for those grown in the solution cultures. Incidentally there was a marked difference between the solutions producing the highest yield of plants in sand and those giving the best growth in Shive's cultures.

Livingston and Tottingham (8) made a preliminary test of a series of type III solutions, containing the three component salts KNO_3 , $\text{Ca}(\text{H}_2\text{PO}_4)_2$, and MgSO_4 . Their results showed that the solution III R6C1 was apparently just as good as Shive's best IR5C2 solution. However, this experiment lasted only 18 days.

Shive (20) and Shive and Martin (22) studied the salt requirements of young and of mature buckwheat plants in both solution and sand cultures. They found that the solution yielding the maximum weight of tops during the early developmental period, and the solution that gave the highest yield of tops and of roots during the late period of development, were identical for both the solution and the sand cultures, but the actual dry weight of

¹ Tottingham (25) has presented an extensive review of literature covering the subject of solution cultures. For citations see pages 242-245.

the plants was considerably greater for the sand cultures than for the solution cultures.

Meier and Halstead (14) ran a series of wheat experiments with Shive's three-salt solution, each series comprising 21 cultures of different salt proportions all having an osmotic concentration of one atmosphere. They found that no one culture gave consistently high yields of plants, and noted, as did Livingston (6), Shive (19), McCall (10), Wolkoff (27), and others, that the total amount of transpiration is as good a criterion as is the final dry weight of plants for studying the comparative growth obtained in different solutions.

Bouyoucos (1) observed that the amount of transpiration per gram of dry matter tended to be larger in the sand than in solution cultures receiving the same densities of solution, while the actual dry matter produced was greater in the solution than in the sand cultures. Lyon and Bizzell (9) found that wheat seedlings growing in crushed quartz containing the same nutrient solutions as those used in water cultures produced the same relative quantities of dry matter per unit of transpiration as did the water cultures, but the quantitative production of dry matter per unit of transpiration was in each case greater in the quartz than in the water cultures.

Certain investigators, McCall (10), Lyon and Bizzell (9), and others, claim that the superiority of sand cultures over solution cultures is due primarily to the adsorptive properties of the sand particles. Wolkoff (27) concluded from his work that adsorption was not the factor which modified the concentration of the solution to such an extent as to cause even slight differences in plant growth. Shive (21) also found no evidence of the adsorption of salts or ions in sufficient amounts to change the total concentration of the solutions.

In recent years considerable attention has been devoted to studying the effect of the reaction of the medium of sand and water cultures on the growth of plants. Hoagland (4) studied the effect of hydrogen- and hydroxyl-ion concentration on barley seedlings growing in partial nutrient solutions of like osmotic pressure. He noted that the OH ion was more toxic than the H ion for similar divergencies from the neutral point. Later the same author (5) found that an acid solution (pH 5) was not injurious to the barley plant at any period in its growth. As in his previous work, he observed a tendency on the part of the plant to adjust the reaction of the medium toward the neutral point. Toole and Tottingham (24) also noted that barley seedlings had a marked neutralizing effect on the nutrient solution, and that the solution in which the plants had been grown showed a more nearly uniform hydrogen-ion concentration than did the original solution. They found that the weights of dry tops of barley were inversely proportional to the hydrogen-ion concentration of the solution.

Duggar (2) concluded from his work that the tendency for the shifting of an acid reaction toward the neutral point depends in part upon the

composition of the solution and in part upon the plant grown. Shive (21) demonstrated that the reaction of a nutrient solution is not noticeably changed by being in contact with sand. Salter and MacIlvaine (15) studied the effect of reaction of solution on germination and on growth of seedlings of wheat, soybeans, corn, and alfalfa. The maximum growth of wheat, soybeans, and alfalfa was obtained in a solution having a reaction of 5.94 pH. The maximum growth for corn was obtained at 5.16 pH. These authors noted that the OH ion is more harmful than the hydrogen ion in equivalent concentrations. Meier and Halstead (14) reported that there is no correlation between the yield of plants and the hydrogen-ion concentration or the change in pH. McCall and Haag (13) varied the hydrogen-ion concentration in different nutrient solutions, and noted that the hydrogen-ion concentration has a marked effect upon the rate of growth of the wheat plant and is an important factor in the control of chlorosis.

The object of the work reported in this paper was to determine the best proportion of the three salts KNO_3 , $\text{Ca}(\text{H}_2\text{PO}_4)_2$, and MgSO_4 for the growth of wheat, and also to compare the sand- and water-culture methods with respect to transpiration, total weight of tops and roots, and the reaction of the media as determined by means of the hydrogen electrode.

TABLE 1. *Partial Volume-molecular Concentrations and Molecular Proportions of KNO_3 , $\text{Ca}(\text{H}_2\text{PO}_4)_2$, and MgSO_4 in 21 Solutions all having an Osmotic Value of Approximately 1.00 Atmosphere at 25°C. but Differing by Increments of One Eighth in the Salt Proportions*

Solution Number	Molecular Proportions			Partial Volume-molecular Concentrations		
	KNO_3	$\text{Ca}(\text{H}_2\text{PO}_4)_2$	MgSO_4	KNO_3	$\text{Ca}(\text{H}_2\text{PO}_4)_2$	MgSO_4
III						
R1S1	1	1	0	.0027	.0027	.0165
S2	1	2	5	.0026	.0053	.0132
S3	1	3	4	.0024	.0073	.0098
S4	1	4	3	.0023	.0093	.0070
S5	1	5	2	.0021	.0100	.0042
S6	1	6	1	.0021	.0125	.0021
R2S1	2	1	5	.0051	.0027	.0135
S2	2	2	4	.0048	.0048	.0096
S3	2	3	3	.0045	.0067	.0067
S4	2	4	2	.0042	.0084	.0042
S5	2	5	1	.0041	.0103	.0020
R3S1	3	1	4	.0075	.0025	.0090
S2	3	2	3	.0070	.0047	.0070
S3	3	3	2	.0067	.0067	.0045
S4	3	4	1	.0064	.0086	.0021
R4S1	4	1	3	.0099	.0025	.0074
S2	4	2	2	.0094	.0047	.0047
S3	4	3	1	.0085	.0064	.0021
R5S1	5	1	2	.0125	.0024	.0048
S2	5	2	1	.0113	.0045	.0023
R6S1	6	1	1	.0139	.0023	.0023
Shive's R5C2, 75% atm.	3.77	1.00	3.14	.0180	.0052	.0150

EXPERIMENTAL

The plan of the experiment was in all its essential details the same as that recommended by the Special Committee of the National Research Council on Salt Requirements of Agricultural Plants (23).

The salts used were especially prepared for this work at the request of this committee by the J. T. Baker Chemical Company. The molecular proportions and partial volume-molecular concentrations of the three salts, KNO_3 , $\text{Ca}(\text{H}_2\text{PO}_4)_2$, and MgSO_4 , are given in table 1. These dilutions are based on freezing-point determinations made by Dr. Shive.

The wheat used was of the "Marquis" variety, secured through Dr. Stakman of the University of Minnesota. In the matter of securing uniform seedlings of 4 cms. length, the seeds were first soaked in a germinating solution (Shive's R_5C_2 , 0.1 optimal concentration), and later distributed evenly upon a germinating net made by taking ordinary mosquito netting which had been thoroughly paraffined; this net was tied tightly over a 5-gallon glazed stoneware jar. Provision was made so that two liters of fresh germinating solution could be added from the bottom of the container each day. In order to maintain a temperature of approximately 18°C ., the jar was kept in a water bath. It then became a simple matter to secure the seedlings of desired uniformity. For the water cultures the seedlings were mounted in cork stoppers to fit 1-quart Mason jars in the manner adopted by Tottingham. Five plants were used for each culture.

The sand used was obtained from the Clayton Sand Company of Clayton, Iowa, and gave a mechanical analysis as follows:

Millimeter* in Diameter				
1.00-0.5	0.5-0.25	0.25-0.10	0.10-0.05	0.05-0.00
0.00%	62.80%	14.12%	21.40%	1.62%

A chemical analysis showed the sand to contain 98.5 percent SiO_2 and 0.54 percent iron and aluminum hydroxide. It had a water-holding capacity of 21 percent on the dry-weight basis. [Hilgard method with column 1 cm. high (3).]

Regarding the optimum moisture content of a soil as 50 percent of its maximum water-holding capacity, the sand cultures were maintained at a moisture content of 11 percent.

After the experiment had been in progress for one month, it was realized that the 11 percent moisture was not sufficient to supply the needs of maximum transpiration, and consequently the moisture content was raised to 16 percent for the remaining period of experimentation.

Glazed stone or butter jars 12.5 cm. high and 19.0 cm. in diameter were used for these cultures. A glass suction tube, the lower end of which was

loosely plugged with glass wool, was vertically placed against the wall of the jar. Its lower end rested on the bottom of the jar and the upper end extended just above the rim. The tube was held in place while the sand was added. Each jar was filled with 1250 grams of carefully washed sand.

For the supply orifice, 100-cc. wide-mouthed bottles with the bottoms removed were used. Each bottle rested on an inverted glazed porcelain dish according to the method of McCall and Richards (11). After five seedlings were transferred to the sand medium, enough solution was added through the mouth of the bottle to bring the liquid to about 1 cm. above the sand, and the crock was slightly jarred to settle the sand about the roots of the seedlings and to give a level surface for the wax seal (80 parts paraffin, 20 parts vaseline). The outlet tube was then connected with a vacuum pump, and the excess solution was drawn off. The sand was flooded again, and suction was applied until the moisture content was optimum.

When the seedlings were in place the total weights of cultures were recorded. All solutions were renewed twice a week throughout the continuance of the experiment. At the time, the cultures were weighed and the amount of water lost by transpiration was recorded.

The growth period extended from January 15, 1921, to March 24, 1921, which brought the plants to the stage at which the advanced cultures were just beginning to head.

Determination of Hydrogen-Ion Concentration

After the plants were harvested from the sand and water cultures, samples were taken from each culture for the purpose of determining the hydrogen-ion concentration of the medium after the plants had grown in it for one $3\frac{1}{2}$ -day period.

The apparatus used in this work included the following pieces obtained from the Leeds and Northrup Company: potentiometer, 3-dial resistance box, Wall d'Arsonval galvanometer (type P), Eppley standard cell, single-contact key, one double-throw switch, and two dry-cell batteries. An Ostwald normal calomel electrode and a Hildebrand hydrogen-gas electrode were used. The hydrogen, obtained from a tank of compressed hydrogen, was purified by bubbling through a 5-percent solution of potassium permanganate, then through a 5-percent solution of pyrogallie acid, and finally through distilled water. The hydrogen-electrode vessel used was similar to the one described by Sharpe and Hoagland (18), consisting of a small wide-mouthed bottle of 75 cc. capacity. This was fitted with a rubber stopper into which were inserted the hydrogen electrode, a small exit tube, and a small bent glass tube filled with agar jelly saturated with KCl. Connection was made with the calomel cell by means of a beaker containing a saturated KCl solution and the agar tube.

The solution or suspension to be tested was placed in the hydrogen-

electrode vessel and hydrogen gas was bubbled through for several minutes. The exit tube was then closed and the vessel was shaken for two minutes, after which processes a reading was made. These processes were repeated until a constant reading was obtained. The voltmeter readings were transformed into pH values from the tables prepared for this purpose by Schmidt and Hoagland (16).

Results

When the more advanced cultures were just beginning to head out, each culture, containing five plants, was harvested as a whole in the usual manner. The tops were placed in weighed beakers, and the green weights were recorded. They were then dried to constant weight in an electric oven. Likewise, the roots were dried in the same manner and weighed. The roots of the sand cultures were first thoroughly washed free from sand.

The data for total absorption, fresh and dry weights of tops, and the dry weight of roots for the sand and water cultures are given in table 2. The five sand and water cultures showing the greatest transpiration, the highest fresh weight of tops, and the largest dry weight of tops and roots are marked *H*. Likewise the five lowest cultures in each case are marked *L*.

TABLE 2. *Total Absorption for the Growth Period, the Fresh Weight of Tops, and the Dry Weight of Tops and Roots, of Water and Sand Cultures*

Solution Number	Total Absorption (grams)		Fresh Wt. of Tops (grams)		Dry Weight			
	Water	Sand	Water	Sand	Tops (g.)		Roots (g.)	
					Water	Sand	Water	Sand
III (1.00 atm.)								
R181	4860	3685	44.6	24.1	9.786H	5.461	2.741H	5.998
S2	4254	3655	37.8	24.5	7.626	5.731	2.951H	7.066H
S3	3174	1774L	32.5	7.9L	5.748	1.693L	1.996	2.183L
S4	382L	2248L	2.5	12.1L	0.125L	2.597L	0.198L	3.947
S5	167L	1576L	0.7L	4.3L	0.025L	1.364L	1.146L	22.072L
S6	91L	998L	0.1L	1.9L	0.041L	0.857L	0.082L	1.669L
R281	6203H	3935	65.5H	31.7	15.828H	6.045	2.730	6.678H
S2	4647	4078	48.0	33.2	12.860H	6.992	2.490	12.547H
S3	3997	3526	47.0	37.5	7.126	5.398	2.454	7.254H
S4	1503	3882	4.5	29.9	1.677	7.262	0.493	6.360
S5	120L	2730L	0.3L	18.3L	0.140L	3.945L	0.138L	3.589
R381	4922	3778	47.8	36.3	10.147H	5.857	2.507	4.391
S2	5825H	4312	62.7H	36.4	9.440H	7.812H	3.867H	7.461H
S3	3430	4490H	38.0	43.2H	4.369	8.992H	1.992	5.740
S4	288L	4253	1.0L	34.3	0.275L	7.389	0.222L	4.894
R481	4936	4450H	55.1H	32.0	8.861	5.462	2.413	1.858L
S2	4905	4578H	55.0H	30.0H	7.080	7.880H	3.675H	3.048
S3	518	4377H	1.9L	45.2H	0.396	8.665H	0.244	3.215L
R581	5207H	4254	60.0H	38.3	9.050	0.142	2.260	5.261
S2	5306H	4707H	53.2	48.2H	6.726	7.981H	2.830H	2.004
R681	5063H	4305	52.0	38.5H	7.593	6.123	1.063	2.476
Shive's R5C2								
(1.75 atm.)	3147	3514	34.2	26.6	5.563	4.695	2.582	2.895
	3669	3323	23.0	20.7	7.365	4.141	3.355	2.526

Considering first the absorption data presented in table 2, it will be seen that the amount of water absorbed or lost by transpiration from the water cultures is very much greater, with few exceptions, than it is from the sand cultures. It is interesting to note that the sand cultures transpiring more water than the water cultures are characterized by having a high proportion of $\text{Ca}(\text{H}_2\text{PO}_4)_2$ with only a small proportion of KNO_3 and MgSO_4 . The five water cultures showing the greatest absorption (marked *II*) are not the same as the five sand cultures showing the greatest absorption, with the exception of culture R5S2. The five cultures showing the lowest absorption are the same for both sand and water cultures with but a single exception. In the case of the control solutions, the quantity absorbed is practically the same for both sand and water cultures. However, the total absorption for the control solutions is very much lower than that for the five sand and water cultures marked *II*. These transpirational data, therefore, show a marked superiority of type III solution over Shive's "best" solution (R5C2—1.75 atm.).

Three of the five water cultures showing the greatest absorption also have the highest fresh and dry weight of tops, while four of the five sand cultures marked *II* reveal this relation. Thus, in general these data uphold the conclusion of Livingston (6) and of other writers that the amount of transpiration appears to be as good a criterion as the final dry weight for judging the comparative growth obtained in different solutions.

A comparison of the fresh and dry weight of tops produced by the sand and water cultures shows that the highest yields favor the water cultures with the exception of those cultures having high concentrations of $\text{Ca}(\text{H}_2\text{PO}_4)_2$. But the sand cultures favor the greatest growth of roots, as shown by a comparison of the dry weight of roots grown in the sand and water cultures. By comparing the dry weight of tops produced by the high-yielding sand and water cultures with the average dry weight of tops produced by the control solution (Shive's R5C2), it will be seen that the water culture III R2S1 is superior to Shive's R5C2 by 144 percent, while the sand culture III R3S3 is superior to Shive's R5C2 by 103 percent. When the dry weight of roots of III R3S2 of water cultures is compared with the dry weight of roots of Shive's R5C2 there is a difference of 30 percent. These differences are great enough to overbalance any possible errors in plant variation, and furnish conclusive evidence that the optimum proportion of salts in type III solution gives better growth for wheat than Shive's (R5C2—1.75 atm.) solution.

In comparing the data given in table 4, it is clear that there is very little difference in the total dry weight (tops and roots) of the sand and water cultures. On the total dry-weight basis, the average increased yield of the best sand and water cultures of type III solution over the average yield of Shive's solution is 131 percent.

As a means of facilitating comparison of the salt requirements of wheat

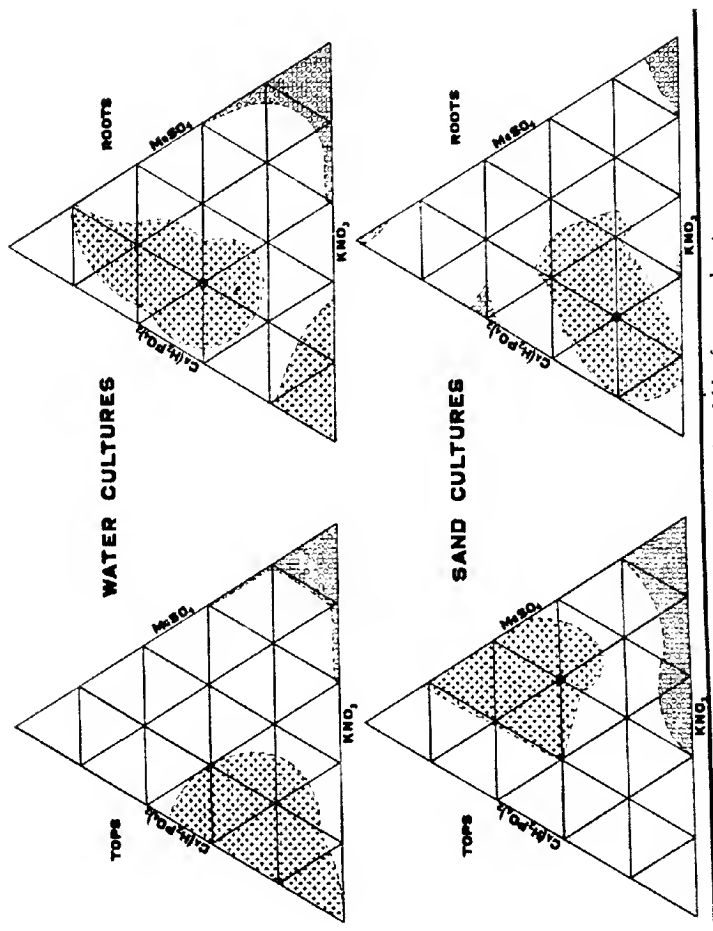


FIG. 1. Diagrams showing relative yields of tops and roots.

when grown in sand and water cultures, use has been made of the triangular diagram in discussing these results. This scheme was first suggested for this kind of work by Schreiner and Skinner (17) and was later modified and perfected by Tottingham (25), Shive (19), McCall (10), and Trelease (26). The details of the arrangement of the cultures in the triangle are given by all of the above-named authors and also by the plan of the committee (23). The triangular diagrams for the dry weights of tops and roots for water and sand cultures are shown in figure 1. The five cultures lying in the high-yielding areas, marked *H* in table 2, are plotted on the triangles with small + signs. Similarly, the five cultures lying in the low-yielding areas, marked *L* in table 2, are plotted on the triangles with small circles. This method was suggested by Shive (19). The culture having the highest yield in each diagram is marked with a circle.

In figure 1, comparing first the triangles representing the dry weight of tops of wheat plants grown in water and sand cultures, the five high-yielding water cultures (15.82-9.44) occupy the lower left position of the triangle, whereas the five high-yielding sand cultures (8.99-7.84) assume the upper right central portion of the triangle. Thus it is seen, as noted by McCall (10), that the water cultures and sand cultures show a marked difference in the salt proportions that are required to produce their respective maximum yields of tops. At only one point, that of R3S2, do the areas overlap, and this is the lowest culture of the five in both cases. The highest-yielding water culture (R2S1) has the following molecular proportions: 2, KNO_3 ; 1, $\text{Ca}(\text{H}_2\text{PO}_4)_2$; and 5, MgSO_4 . The partial volume-molecular concentrations are 0.0054 KNO_3 , 0.0027 $\text{Ca}(\text{H}_2\text{PO}_4)_2$, and 0.0135 MgSO_4 . In other words, the solution is made with 18.90 cc. (1.0 M) KNO_3 , 94.5 cc. (0.1 M) $\text{Ca}(\text{H}_2\text{PO}_4)_2$, 47.25 cc. (1.0 M) MgSO_4 , and 3 mg. FePO_4 made up to 1 liter with distilled water. The highest-yielding sand culture (R3S3) has the following molecular proportion: 3, KNO_3 ; 3, $\text{Ca}(\text{H}_2\text{PO}_4)_2$; and 2, MgSO_4 . The partial volume-molecular concentrations are 0.0067 KNO_3 , 0.0067 $\text{Ca}(\text{H}_2\text{PO}_4)_2$, and 0.0045 MgSO_4 . This solution is made with 23.45 cc. (1.0 M) KNO_3 , 234.5 cc. (0.1 M) $\text{Ca}(\text{H}_2\text{PO}_4)_2$, 15.75 cc. (1.0 M) MgSO_4 , and 3 mg. FePO_4 made up to 1 liter with distilled water.

The five low-yielding water cultures (0.125-0.412) occupy the extreme lower right apex of the triangle, and the same is true for the five low-yielding sand cultures (0.856-3.94).

A comparison of the triangles representing the dry weight of roots of the sand and water cultures also shows a wide difference in salt proportions, though not as great as in the case of the tops. Four of the five high-yielding water cultures (3.86-2.74) are located on the line of cultures deriving two eighths of their total molecular proportions from $\text{Ca}(\text{H}_2\text{PO}_4)_2$. The highest-yielding culture (marked with a circle) is characterized by having two eighths of its total diffusion tension due to $\text{Ca}(\text{H}_2\text{PO}_4)_2$; three eighths due to KNO_3 ; and three eighths due to MgSO_4 . The area of the high-yielding

sand cultures (12.54-6.67) is found in the lower left central portion of the triangle.

The position of the low-yielding root cultures of the water series is identical with that of the low-yielding top cultures, but this relation does not hold true, at least under the present experiment, for the sand-culture series.

Climatic Conditions

In order that environmental conditions might be as uniform as possible, the cultures were placed upon two revolving tables. The water cultures occupied one and the sand cultures the other.

The following aerial records were secured for the entire growth period: (1) temperature; (2) evaporating power of the air; (3) amount of radiant energy absorbed; and (4) number of hours of sunshine.

Temperature records were obtained from a thermograph placed near the revolving tables. The evaporating power of the air was measured by means of white and black standardized spherical porous-cup atmometers (Livingston, 7). The atmometers were weighed after each 3½-day interval and cleaned once a week. The amount of radiant energy (Livingston, 7) absorbed was determined by the difference in the losses between the corrected readings of the black cup and the readings of the white cup. The duration of sunshine data was kindly furnished by Mr. Charles D. Reed of the United States Weather Bureau office at Des Moines, Iowa. The data relating to environmental conditions are given in table 3.

TABLE 3. *Weekly Averages of Climatic Conditions for the Growth Period*

Date Week Ending	Evaporating Power of Air		Radiant Energy Ab- sorbed	Sun- shine	Temperature		
	Loss White Sphere	Loss Black Sphere			Average Maxi- mum	Average Mini- mum	Mean
	G.	G.	G.	Hours	°C.	°C.	°C.
January 24	82.7	105.8	23.1	38.6	23.1	12.9	18.0
31	64.2	76.8	12.6	18.5	22.0	12.1	17.1
February 7	59.8	76.9	17.1	27.1	23.2	12.6	17.9
14	69.5	94.6	25.1	33.6	21.7	13.2	17.5
21	84.5	120.4	35.9	71.2	25.0	10.8	17.9
28	74.8	102.3	27.5	48.2	30.0	16.7	23.4
March 7	70.4	80.3	9.9	45.5	27.6	13.9	20.8
14	64.2	105.8	41.0	33.7	25.8	14.8	20.3
21	92.4	135.0	42.6	72.6	31.7	12.9	22.3
24	36.1	49.0	12.9	14.4	20.8	18.1	22.5
Total	608.6	946.9	248.3	403.4	—	—	—
Daily average	10.1	13.7	3.6	—	25.5	13.6	19.6

An examination of the data presented in table 3 shows that the plants

were grown during a period of very unfavorable climatic conditions. There was an unusual amount of cloudiness, as is very evident from the total number of hours of sunshine and the correspondingly low absorption of radiant energy. The mean temperature for the growth period was also lower than that regarded as optimum for the growth of wheat. Under more favorable growing conditions it is possible that the results herein reported would be different.

The data for the hydrogen-ion concentration of type III solutions before growing cultures are taken from the work of McCall and Haag (12). The data for the hydrogen-ion concentration determinations of the solutions after the plants had been grown in them for the last 3½-day period, and the total dry weight per culture for the sand and water cultures, are given in table 4.

TABLE 4. *Showing Hydrogen-ion Concentration of Type III Solutions before Growing Wheat, after the Last 3½-day Interval, and the Total Dry Weight of Tops and Roots of Sand and Water Cultures*

Solution Number	Before Growing Cultures	After Growing Cultures				Total Dry Weight
						Tops and Roots
		Water	Sand	Water	Sand	
III	pH	pH	pH	Grams	Grams	
R1S1	4.1	5.98	6.79	12.527H	17.459H	
S2	3.7	5.32	6.72	10.577	12.737	
S3	3.6	5.05	6.64	7.744	3.876L	
S4	3.6	4.39	6.34	0.323L	6.544L	
S5	3.6	4.83	6.08	0.171L	4.036L	
S6	3.6	3.65	6.12	0.123L	2.726L	
R2S1	4.1	7.20	6.99	18.558H	12.723	
S2	3.7	5.90	6.81	15.350H	19.539H	
S3	3.6	5.56	6.74	9.580	12.652	
S4	3.6	5.07	5.98	2.170	13.622H	
S5	3.5	5.12	5.88	0.278L	7.534	
R3S1	4.1	7.20	7.03	12.654H	10.248	
S2	3.7	6.98	6.88	13.307H	15.303H	
S3	3.6	5.74	6.50	6.361	14.732H	
S4	3.6	5.24	6.44	0.497L	12.283	
R4S1	4.1	6.98	7.09	11.274	7.320L	
S2	3.7	6.57	7.15	11.655	11.528	
S3	3.6	5.99	6.49	0.640	11.880	
R5S1	4.1	7.08	7.33	11.310	11.403	
S2	3.7	6.94	6.91	9.565	10.885	
R6S1	3.9	7.92	6.98	9.256	8.599	
Shive's R5C2	3.4	5.54	6.30	8.145	7.500	
(1.75 atm)		5.41	6.47	10.720	6.667	

The data presented in table 4 show that before growth this solution had a rather acid reaction. After being in contact with the plants for only 3½ days there was a decided change in the hydrogen-ion concentration.

The approach toward neutrality is more striking for the sand cultures than it is for the solution cultures. This statement is particularly true of the control solutions. In the control water cultures the reaction had changed after $3\frac{1}{2}$ days to the extent of 1.0 pH toward neutrality, whereas in the sand cultures it changed from 4.4 pH to 6.38 pH, or a decrease in acidity of 2.0 pH. These data would seem to lend support to the adsorption theory, in that the sand particles apparently have adsorbed sufficient anions from the solutions to cause these differences in pH values, and hence favor greater root development in the sand cultures. The water cultures giving the greatest dry weight of tops and of roots have pH values ranging from 5.90 to 7.20. The sand cultures having the largest total dry weight of tops and of roots have pH values ranging from 5.98 to 6.88. However, an examination of these data in table 4 shows no correlation between total yield of dry matter and the hydrogen-ion concentration.

SUMMARY AND CONCLUSIONS

The work reported in this paper has offered a means of comparison of sand and water cultures of Marquis wheat when grown in nutrient solutions of type III. Each series of solutions contained 21 cultures of different salt proportions, varied in increments of $\frac{1}{8}$ and all having a total osmotic concentration value of 1.00 atmosphere. The salts used were KNO_3 , $\text{Ca}(\text{H}_2\text{PO}_4)_2$, and MgSO_4 , together with a "trace" of FePO_4 . The main conclusions to be drawn from this study are as follows:

1. The solutions producing the maximum yield of tops for the sand and water cultures showed marked variations in salt proportions. The "best" water-culture solution (R_2S_1) was characterized by having two eighths of its total osmotic concentration derived from KNO_3 ; one eighth from $\text{Ca}(\text{H}_2\text{PO}_4)_2$; and five eighths from MgSO_4 . The "best" sand-culture solution (R_3S_3) had three eighths of its total osmotic concentration due to KNO_3 ; three eighths to $\text{Ca}(\text{H}_2\text{PO}_4)_2$; and two eighths to MgSO_4 .
2. The high-yielding water culture R_2S_1 was far superior to that in Shive's R_5C_2 solution. The high-yielding sand culture also gave much greater production than the control solution.
3. The largest amount of absorption and the maximum green and dry weight of tops favored the water cultures. The greatest root development was obtained from the sand cultures.
4. In general, those cultures having the greatest transpiration for the entire growth period also showed the greatest dry weight of tops and of roots.
5. The reaction of the medium in which the plants were grown changed from an average acidity of pH 3.75 before growing the wheat cultures, to an average acidity of pH 5.94 for the water cultures, and to pH 6.66 for the sand cultures, after growing the plants for one $3\frac{1}{2}$ -day period. No

correlation could be shown between the total yield of cultures and their corresponding hydrogen-ion concentration values.

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THE GREGARIOUS FLOWERING OF THE ORCHID *DENDROBIUM CRUMENATUM*

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Whenever a number of individuals of the orchid *Dendrobium crumenatum* Lindl. occur within the same general locality the plants flower simultaneously.

Such gregarious flowering is met with in other plants: for example, in certain bamboos such as *Bambusa arundinacea* (1), *Phyllostachys puberula* (2), and *Chusquea abietifolia* (3). There are, however, two striking differences between the simultaneous flowering of the orchid and that of bamboos. First, in the latter case the flowering is rhythmic. In bamboos which exhibit rhythmic sexual periodicity the time between periods of flowering, i.e., the life of the plant, is about thirty-two years (3, 4). In *Dendrobium* the periods between flowering dates vary from a few days to several months. A glance at the dates of flowering in table 1 is sufficient to reveal the fact that there is no rhythmic periodicity here. The second striking difference between the gregarious flowering of orchids and that of bamboos is that in the latter case all the individuals of a bamboo forest are of the same age, while among an assemblage of orchids the individuals may be of quite different ages. In the case of bamboos there is accordingly good reason to regard the sexual periodicity as the expression of an innate, heritable character (3). The lack of rhythm in the flowering of the orchid and the differences in the ages of the plants which flower gregariously suggest that simultaneity here is possibly due to an external factor. The following additional observation tends further to support this belief.

Among the specimens of *Dendrobium crumenatum* in the Botanic Gardens at Buitenzorg, Java, there are plants collected from nearly all parts of the Dutch East Indies, from Riouw (near Singapore), from Sumatra, Java, Borneo, Celebes, and Ambon (a small island at the eastern end of the archipelago). These plants, shortly after being brought to Buitenzorg, all flowered on the same day, if they flowered at all; yet in their native habitats the flowering periods of the plants do not at all coincide. Thus, orchids growing in the virgin mountain forests flower on different days from those in the lowlands. Plants growing at two stations but three kilometers apart may differ in their times of flowering by one or two days. But wherever their original home and whatever the date of flowering there, the plants, when assembled in one locality, flower simultaneously with each other and with the plants which have grown in that locality from youth. Without

further investigation one would feel convinced on the basis of these facts that simultaneous flowering in *Dendrobium crumenatum* is attributable to some environmental influence.

Before considering what the determining external factor might be—the question with which this paper is chiefly concerned—it will be well to consider first how far we are justified in regarding the environment as the cause of *simultaneity* in flowering. It is conceivable that the gregarious anthesis of *Dendrobium* is actually the expression of the heritable disposition of the plants, and that the external environment determines only the exact *time* at which the gregarious flowering shall take place.

If we regard the plants of *Dendrobium crumenatum* which are growing in any one locality as forming their flower buds uninfluenced to any marked degree by the external environment, and as developing these buds to a definite, and in every case the same, stage of advancement, at which point growth is stopped, then we should expect that there will be at any one time many resting buds all of the same age. This being true, it is evident that, if a stimulus starts all these resting buds growing again at the same time, they will all burst into flower on the same day, assuming that the time required to cover the final lap of their development is constant in all the individuals of the species. This is what Rutgers and Went (5) believe to be the explanation of simultaneous flowering in *Dendrobium crumenatum*. The explanation is analogous to that of the "trigger type" of reaction (shock reaction) in animal behavior. The organism is "primed and cocked." The requisite external stimulus functions merely as a means of releasing the "trigger."

If this hypothesis is correct, then the environmental factor in question determines merely the *exact time* when the resting buds shall recommence growth, complete their development, and come into flower. *Simultaneity* of flowering rests upon the fact that the resting buds, which are apparently aroused to further activity by an environmental factor, are all of the same age and all require the same length of time to complete development; that is, *simultaneity* is due to an innate, heritable factor.

Buitenzorg is renowned for its equable climate. Tropical regions in general vary little throughout the year in temperature, but there is usually a pronounced seasonal change in moisture. No such alternation of wet and dry seasons occurs at Buitenzorg. Where, therefore, the annual precipitation is abundant and so uniformly distributed throughout the year, and where other evident environmental factors, such as temperature and light, are so constant as at Buitenzorg, it is difficult to appreciate what external stimulus might be responsible for the final development and ultimate bursting into flower of *Dendrobium* buds.

Burkill (6), from data obtained in the Straits Settlements, comes to the conclusion that "climatic conditions some eight days in advance of the flowering are a controlling factor" in the gregarious anthesis of *Dendrobium crumenatum*.

The data of Burkill consist in the dates of simultaneous flowering of the pigeon orchid for four years (twenty-seven flowering periods in all) and the daily rainfall figures for these years. When the two groups of data are arranged in a table, it is to be noticed that in most instances the precipitation is unusually heavy on the eighth (sometimes the seventh or ninth) day before each anthesis. Especially evident does this fact become when one considers the total rainfall for each series of days preceding all the flowering periods. The total for the eighth series of days is greater than that of any other. But among the rainfall data preceding each flowering date there are some prominent exceptions. These undoubtedly caused Burkill to conclude that

It is not probable that the volume of the rain which falls exercises any direct influence on the flower buds; but it is quite probable that the changes in temperature accompanying heavy rainfall . . . determine the occurrence.

Wishing to ascertain if the theory of Burkill is supported by the relation between rainfall and the flowering of *Dendrobium crumenatum* at Buitenzorg, Java (where climatic conditions differ considerably from those prevailing at Singapore), I have compared the days of flowering of the orchids and the daily rainfall for twenty-seven days preceding these flowering periods at Buitenzorg. These data are arranged in table 1.¹

If we study the table, the first evident and striking fact is that, of the precipitation totals of the various days which precede each flowering date, that of the eighth—the day on which Burkill found the total rainfall to be at the maximum—is here also the greatest. The total rainfall occurring on the eighth day previous to all the flowering dates is five ninths greater than that of the next highest. Thus, at the very outset, do we have strong support of Burkill's hypothesis. If we examine the table more critically, further favorable evidence is found.

In several instances prolonged dry periods are broken by rainfall on the eighth day before a flowering date (e.g., Oct. 1, 1895; Aug. 25 and Sept. 23, 1896; and Aug. 24, 1919). A shorter dry period is broken on the eighth day preceding the flowering on Nov. 13, 1896, and on Sept. 3, 1919). It will be noticed that in each of these cases the amount of flowering was abundant.

In some instances the heavy rainfall occurred a day later or two or three days earlier. These slight divergencies can be regarded as variations of not sufficient greatness to affect materially the theory. Other exceptions exist, however, which are more disturbing. Thus, on Sept. 7, 1894, April 8, and Dec. 10, 1895, very heavy rainfall occurred on the fourteenth or fifteenth day preceding flowering. One wonders why these precipitations (and even that taking place on the twenty-seventh day preceding Oct. 17, 1894, for example) did not occasion gregarious flowering in the orchids eight days

¹For the dates of blossoming of *Dendrobium crumenatum* I am indebted to Dr. J. J. Smith, Chief of the Buitenzorg Herbarium. For the precipitation data my thanks are due to the Meteorological Observatory of Batavia, Java.

TABLE 1. Table Correlating the Days of Flowering of the Orchid *Dendrobium crumenatum* with the Daily Rainfall Preceding each Flowering Date

27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1		
1	5	1	2	2	2	1	1	26	10	3	27	2	16	2	5	10	—	—	—	21	23	4	8	15	12	39	4	II
2	3	30	1	2	4	1	18	6	17	13	6	3	1	2	5	10	—	—	—	31	4	5	17	12	7	9	43	II
3	1	11	47	20	16	2	4	10	6	1	4	1	1	1	2	3	—	—	—	13	5	17	18	2	47	11	11	II
4	1	15	28	24	2	10	2	1	1	13	7	73	13	1	3	3	—	—	—	5	2	3	8	—	2	47	11	11
5	6	49	23	70	6	—	—	1	1	5	3	2	1	28	9	16	4	—	—	2	2	—	15	—	3	—	11	II
6	3	2	1	5	6	—	—	1	1	3	2	1	86	1	—	—	—	—	—	62	30	—	—	—	3	—	11	II
7	3	1	86	3	—	—	16	4	5	—	—	—	—	3	—	—	—	—	4	5	—	—	—	—	—	—	28	II
8	109	6	16	38	—	—	11	1	—	10	2	2	6	1	3	13	5	—	—	14	152	2	55	—	23	—	21	1
9	2	55	9	78	27	4	2	1	12	—	—	—	—	1	38	—	—	—	2	38	—	31	—	—	—	—	18	November
10	78	9	25	18	—	—	15	5	24	6	9	62	—	6	24	28	—	—	5	10	4	31	5	10	2	78	1	1
11	4	2	1	—	—	—	8	8	28	2	—	—	—	12	31	—	—	—	8	10	4	21	48	30	10	18	26	IV
12	5	10	11	—	—	—	8	5	10	9	13	109	9	411	6	9	21	—	—	6	40	—	4	8	22	7	11	—
13	43	2	6	59	—	114	1	13	32	4	—	—	—	—	41	—	—	—	—	—	—	—	—	—	—	—	10	—
14	5	22	—	—	21	32	—	—	—	—	66	10	2	—	—	—	—	—	—	12	67	9	16	10	2	—	12	—
15	—	—	—	—	—	51	—	—	—	—	—	—	—	3	—	—	—	—	—	12	97	9	8	15	5	53	11	—
16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	50	—	—	6	—	—	—	—	—
17	—	—	—	—	—	44	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
19	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
21	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
23	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
24	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
25	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
26	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
27	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
11 January, 1894	1 March	5 April	5 May	11 June	17 September	17 October	18 November	24 December	20 December	8 March	20 May	2 July	1 October	1 November	10 December	16 February, 1896	2 March	12 April	19 July	25 August	23 September	23 September	26 August, 1919	26 August,	3 September	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
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—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—</						

In the last column is given the date (day, month, and year) of flowering.

In the second column from the right are Roman numerals indicating the amount of flowering, as follows: I, very slight; II, slight;

III, moderate; IV, abundant; V, very abundant; VI, profuse.

In the other columns, which are numbered consecutively from 1 to 27, is given the amount of rainfall in millimeters for each day, from the first to the twenty-seventh, preceding the day of flowering (the number of days chosen being arbitrary but of a sufficient number to give a wide range of observation).

The total rainfall for all the days which precede by the same length of time each of the flowering dates is given at the bottom of each column headed respectively 1 to 27.

later. Two possible explanations of the exceptions can be given. Either rainfall is not the exciting stimulus, or the plants can not be aroused by heavy precipitation *whenever* it occurs.

If the hypothesis of Rutgers and Went is correct, namely, that bud development to a definite point, the same in all individuals, determines simultaneity of flowering, then those exceptions in which no flowering occurs eight days after a heavy rainfall are explainable on the basis that there were no buds awaiting further development at that time. Perpetual flowering is hardly to be expected. Those other but fewer exceptions in which flowering does occur but without heavy rainfall on the eighth preceding day are explainable only on the assumption that rainfall is not the determining factor. Possibly we are forced to come to this conclusion. But it seems very likely that, whatever the stimulus is, it commonly occurs with heavy precipitation. Burkill believes that changes in temperature probably determine the time of occurrence of flowering. Since changes in temperature usually accompany heavy precipitation and may take place without rainfall, it is quite possible that temperature is the exciting stimulus. As to what the factor actually is we are quite ignorant.

The theory that the *time* of simultaneous flowering of *Dendrobium crumenatum* is determined by a climatic factor commonly associated with heavy rainfall and occurring eight days in advance of the day of flowering is supported by the Buitenzorg data so far presented. Most of the exceptions considered can be more or less satisfactorily brought into general agreement with the theory. There is, however, another and possibly insurmountable objection to the theory.

When two or more successive flowering days occur very close together, it is difficult to conceive of one (the second) lot of buds responding to the requisite stimulus eight days in advance of the flowering date and failing to respond to an identical stimulus which only two days earlier started the first lot of buds on the final stage of their development. A striking example of this was pointed out to me by Dr. Smith of the Buitenzorg Herbarium, and is recorded in the table under the dates of Aug. 24 and 26, 1919.

Considered separately, these two flowering dates fit into the theory perfectly. In both cases the day of flowering was preceded by a heavy rainfall on the eighth (or ninth) day previous to anthesis, and this heavy precipitation ended a long dry period. But when the two flowering days are regarded together, one wonders if the physiological state of the buds is quite so nicely adjusted as to leave some of them unresponsive on Aug. 24th to the same kind of stimulus which two days later, on Aug. 26th, arouses them to further development.

Such a condition is not to be regarded as impossible. In this connection it is worth noting that, while the same plant may produce blossoms on two successive flowering dates, no one shoot of any plant bears blossoms on both of two successive flowering days; that is, if a shoot of a plant

responds to the first stimulus and produces blossoms on the first flowering day, it does not respond to the second stimulus and is bare of blossoms on the second flowering day when other shoots of the same plant are in flower.

Whether or not we are near an accurate knowledge of the precise mechanism involved, it seems safe to conclude: first, that *simultaneity* in the flowering of the orchid *Dendrobium crumenatum* is the expression of an innate, heritable factor; and second, that the exact *time* at which this simultaneous flowering shall take place is determined by an external environmental factor occurring eight days in advance of the flowering date. The precise nature of this environmental stimulus is not irrefutably established. If it is not heavy rainfall it is certainly a factor commonly associated with rainfall.

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AUSTRALASIAN BOTANICAL NOTES I. QUEENSLAND AND NEW SOUTH WALES

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The botanist coming to Australia from Europe or America is at once impressed by the almost complete absence from the native flora of any plants that seem at all familiar. If he is acquainted with the Mediterranean regions or California, he recognizes the eucalypts and Acacias, so commonly planted in those regions, and perhaps he may know a few other characteristic Australian plants that have been introduced into the warmer parts of Europe and America, such, for example, as *Leptospermum*, *Melaleuca*, *Callistemon*, *Grevillea*, and others; but all of these belong to families either quite absent from the northern hemisphere, or very scantily represented there. It is evident that the vegetation of subtropical and temperate Australia has very little in common with corresponding latitudes in the northern hemisphere, and that it indicates a very ancient separation of these two regions.

The relations of the principal land masses in the southern hemisphere within the temperate zone are very different indeed from the corresponding latitudes at the north. Instead of the practically continuous land areas of the northern Eurasian and American continents, there are the relatively small and widely separated areas of Australasia, South America, and South Africa. Not only are these entirely separated from each other, but a broad belt of open ocean lies between them and the Antarctic continent, instead of there being a direct connection with the polar regions such as obtains in the northern hemisphere. As none of these land masses extends into really Antarctic latitudes, and as they are largely surrounded by water, only in the Antarctic continent itself are there to be found regions of severe frost, except at high elevations. In consequence of the prevailing temperate climate, mild winters are the rule, and evergreen vegetation prevails for the most part. Very rarely is the deciduous habit developed, and where this occurs it is due, not to cold, but to drought.

Of the three principal south-temperate regions, that of Australia is much more isolated than that of either South America or South Africa, this being especially true of Western Australia, where the peculiarly Australian vegetation reaches its culmination; and this region shows, perhaps, the highest degree of endemism known anywhere. As might be expected, the south-temperate zone has a less uniform flora than that of the north; but

nevertheless there is sufficient resemblance throughout to indicate former land connections between the different regions in earlier geologic time.

Australia comprises an area slightly greater than that of the United States exclusive of Alaska. Compared to the United States, however, it shows much less variety in its topography.

The southernmost point of Australia proper scarcely reaches the fortieth parallel, and Tasmania is only a little south of this. Hence the southernmost districts have a warm temperate climate, while more than a third of the continent lies to the north of the tropic of Capricorn, and has a tropical climate. The climate, as a whole, has a distinctly continental character, with great range of temperature, especially in the extensive arid central regions.

The principal mountains are in the extreme eastern part of the country, in some places actually on the coast. This eastern mountain region, the eastern highlands, has an abundant rainfall on the coastal side, and it is in this region that the most luxuriant vegetation is encountered. This mountainous country extends from Cape York, the extreme northern part of Australia, along the eastern borders of Queensland and New South Wales, and ends in Victoria. The highest mountain is Mt. Kosciusko, near the borders of New South Wales and Victoria. This is only a little over 7000 feet in height, and next to this are the Bellenden-Ker mountains of northeast Queensland, rising to something over 5000 feet elevation. The rainiest region of Australia is in the immediate vicinity of the Bellenden-Ker range, some stations having an annual rainfall of upwards of 150 inches. The writer visited one of these—Babinda, in August, 1921, where there was a practical demonstration that this is really a rainy district. Already over 200 inches had fallen since the first of the year, and it is safe to say that this was materially added to during his stay of three days. The precipitation falls off rapidly inland, and a large part of the interior receives less than ten inches annually.

While the rainfall is perhaps the most important element in determining the character of the vegetation, the nature of the soil also plays an important rôle. This is especially marked in the tropical and subtropical forests of the eastern coastal districts, where the tropical rain-forest types are mainly restricted to the rich basaltic or alluvial soils, while the Eucalyptus forest is almost confined to sandy soils.

A second region of relatively heavy rainfall is met with in the extreme southwest, where there is a heavy forest growth, but almost exclusively of Eucalyptus.

The plants of Australia fall into three distinct categories. The first of these includes a large number of species, mainly restricted to the coastal areas of Queensland and New South Wales, which are either identical with, or closely related to, Indo-Malayan species. The second, and much the largest, group is made up of the peculiar types which are strictly Australian

in origin. These occur in all parts of the continent, and in many regions, especially in the dryer areas, constitute the entire indigenous flora. Finally, there is a small infusion of temperate genera, such as *Viola* and *Ranunculus*, and several genera which are identical with those of the colder regions of Chile and Patagonia. This latter "Fuegian" element is best developed in Tasmania, but also forms an alpine flora in the highest mountains of New South Wales and Queensland.

An enumeration in 1914¹ of the vascular plants of Australia gave a total number of 10,673 species, which presumably has been considerably added to since that time. According to Mueller, over eighty percent of the species are endemic.

QUEENSLAND

Soon after landing in Sydney, July 26, I proceeded by train to Brisbane, the capital of Queensland, whence I continued my journey by steamer to Cairns, in northern Queensland. This little town, in south latitude 17°, was the northernmost point reached.

The conditions in Cairns are genuinely tropical. Being winter, it was not uncomfortably hot—indeed, after the chilly winds in Sydney and Brisbane, the warm sun was very comforting.

Sailing north from Brisbane, the steamer is within the Great Barrier reef, but this was too far away to be visible. The northern Queensland coast is very rugged, the mountains rising in many places direct from the sea, and there are many picturesque mountainous islands fringing the coast. The southernmost islands and the coast are quite barren, or but scantily wooded, but along the wetter northern coast they are often densely covered with forest. In some places were pure stands of *Araucaria Cunninghamii* looking much like a northern pine forest.

The country immediately about Cairns is flat and sandy. Extensive mangrove formations fringe much of the shore and extend up the shallow creeks which abound along the coast. There are several species of mangroves in Queensland, some, like the common *Rhizophora mucronata*, with stilt roots, while the widespread "white mangrove," *Avicennia officinalis*, sends up myriads of slender pneumatophores from the roots buried in the mud.

About Cairns the forest is rather open, and is in part composed of Eucalyptus, and partly of Ficus and other tropical types. A Pandanus was very abundant, as also were cycads; but, as the latter were not in flower or fruit, it was not possible to tell whether they were Macrozamia or species of Cycas. A conspicuous large shrub was *Hormia alata*, with glossy leaves and large yellow flowers. Wormia is a common member of the strand floras all over Indo-Malaya. In the low ground around the swampy areas which were encountered here and there, were a good many ferns.

¹ Maiden, J. H. Australian Vegetation, p. 166. Federal Handbook for Australia. Melbourne, 1914.

Among the less common types recorded from this region are *Schizaea dichotoma* and *Lygodium*. A few specimens of *Psilotum* were seen, and on one of the pools a mass of *Azolla rubra*, which is not rare in many parts of Australia.



FIG. 1. Mangroves, Cairns, North Queensland.

In the gardens were the usual tropical shrubs—*Hibiscus*, *Poinsettia*, etc.—and some fine tree ferns and epiphytic orchids. Among the latter, a handsome yellow and brown *Dendrobium* (*D. undulatum*) was in full flower. This is said to be common in the neighborhood of Cairns.

To the south of Cairns lies the Bellenden-Ker range of mountains, the highest land in Queensland. Bahinda, lying at the foot of this range, was

visited, but the almost incessant rain prevented much botanizing. This, as already mentioned, is the rainiest district in Australia, and the low wet forests are a veritable jungle, the trees loaded with creepers in great variety and exhibiting extensive groves of palms, comprising several species. Most abundant and beautiful was a graceful Archontophoenix, probably *A. Alexandrae*, but this was not certain. A very peculiar fan palm, *Licuala Muelleri*, was also common, and less abundant was the pretty little "walking-stick" palm, *Bacularia* sp.

Farther north, in the York Peninsula, are several Indo-Malayan genera, *Caryota*, *Borassus*, *Areca*, and others, which were not seen in the Cairns district. The pitcher plants, *Nepenthes*, are also apparently confined to the mountains of York Peninsula. The development of lianas was very striking everywhere about Babinda. Among the most notable were rattan palms (*Calamus*) of several species, several climbing Araceae (*Pothos longipes*, *P. Brownii*, and *Rhapidophora australasica*), *Piper Mestoni*, a species with showy scarlet fruits, and several which were not determined.

Epiphytic ferns, including the conspicuous *Asplenium Nidus* and species of *Polypodium*, were abundant, as well as other epiphytic types, like *Peperomia*.

In the cleared ground were thickets of two species of *Rubus*, and among the various other plants of the open was a rather showy *Melastoma* (*M. Malabathicum*).

Ferns, liverworts, and mosses were not especially conspicuous about Babinda, but along the banks of the streams were fairly abundant. A few small Hymenophyllaceae were noted, and some magnificent specimens of the giant fern, *Angiopteris* sp.

To the west of Cairns the land rises rapidly to a table land, where there is developed perhaps the finest forest in Australia. This forest contains a good many very valuable timber trees, and is rapidly disappearing before the onslaughts of the lumberman. Some fragments still survive near Kuranda, at about 1000 feet elevation, but one has to go much farther inland to find any considerable stands of untouched timber.

The railway from Cairns to Kuranda follows the gorge of the Barron River, which at the head of the gorge forms a fine cataract, the largest in Australia. Below the falls the steep walls of the canyon are heavily wooded, and among the trees can generally be distinguished, here and there, the massive cylindrical trunk and wide-spreading crown of the Kauri pine (*Agathis Palmerstoni*), perhaps the most prized of all the timber trees of this region. Near the brink of the falls, a small piece of forest has been reserved in which are standing two or three fine specimens of this tree, the largest with a girth of about 16 feet.

The forest about Kuranda was somewhat more open than the lowland rain forest, and the trees were taller, often with straight boles of great height. Only one Eucalyptus, *E. tessellaris*, was seen in this district, the

forest being almost exclusively of the Malayan rain-forest type. Lianas in great variety were noted, perhaps the commonest being species of *Vitis*, but climbing *Araceae* like those seen at Babinda were conspicuous, and the



FIG. 2. Rain forest, North Queensland; in foreground and at the right, *Calamus* sp.; in the middle, *Alsophila australis*; on the tree trunk at left, *Asplenium Nidus* and *Pothos* sp.

rattan palms (*Calamus* sp.) made impassable tangles, especially at the edge of the forest. No barbed-wire entanglement could be more impenetrable than a rattan thicket, as one soon learns to one's sorrow. Another dreaded pest of these forests is the tree nettle, *Laportea moroides*, a rank-growing weed some ten or fifteen feet high, whose touch is torture. In southern

Queensland is a second species, *L. gigas*, which is a tree of large size. Among the trees which may be called truly Australian were species of *Grevillea* and *Casuarina* growing mostly in the more open districts. A *Pandanus* was also common, and a true *Cycas*, *C. media*. This genus is found in Australia only in tropical Queensland, and the same is true of the exclusively Australian genus *Bowenia*. The latter, with its bipinnate leaf, suggests a fern like *Pteridium*, rather than a cycad. *B. spectabilis* is not uncommon about Babinda.

Ferns are rather more in evidence than in the lower country. Two species of tree ferns were noted, *Alsophila australis* and *A. Rebeccae*. A few filmy ferns were seen, but these were not common. Other ferns noted were *Marattia fraxinea* and several species of *Adiantum*; *Lygodium scandens* was very common, and *Gleichenia linearis*, *Asplenium Nidus*, and other epiphytic species were frequent.

Through the kindness of Mr. A. H. Belson, of Jungaburra, I had an opportunity of visiting a tract of untouched timber, which gave an excellent idea of the character of the forest of the higher table-land. Jungaburra lies at about 2500 feet elevation, and although it is in latitude 17° or thereabouts, its winter climate is far from tropical. Evidences of severe frost, sufficient to cut back bananas and other tender plants, were to be seen in many places, while at Herberton, at a somewhat higher elevation, fourteen degrees of frost were reported.

The forest near Jungaburra was more open than that at Kuranda, and the lianas and epiphytes were rather less in evidence. Many of the trees are of great size, with tall, straight trunks, often supported by buttresses, so common in the tropical rain forest. Among the trees of this forest, probably the majority were species of *Flindersia*, a genus usually placed in the Meliaceae but referred by Engler to the Rutaceae. Some of these are known locally as "ash," "beech," "maple," "hickory," from some supposed resemblance of the wood to that of these very different trees.

Formerly abundant, but now becoming very scarce, is the "red cedar," *Cedrela toona*, which reaches a gigantic size, sometimes ten feet or more in diameter. Other abundant species noted were *Xanthostemon pubescens*, of the Myrtaceae, *Cryptocarya Palmerstoni*, "black wahu," and *Tarrietia Argrodendron*, "crow's-foot elm." A few fine specimens of *Alagathia Palmerstoni* and *Podocarpus elata* were seen, but these species evidently were not abundant.

In the Queensland "scrubs," the local name for the rain forest, there are several Proteaceae which attain the size of large trees and yield valuable timber known in the trade as oak. The most familiar of these is the "silky oak," *Grevillea robusta*, often grown in California as an ornamental tree; but several other genera occur, viz., *Embothrium*, *Stenocarpus*, *Carnarvonia*, and *Darlingtonia*. The two latter are monotypic.

As in most tropical rain forests, the genus *Ficus* is conspicuous, and in

the neighborhood of Jungaburra are some trees of gigantic size (fig. 3). One, with a compact trunk of closely interlaced roots, was said to have a girth of 120 feet, and the great crown of foliage was in proportion.



FIG. 3. Giant Ficus; Jungaburra, North Queensland.

From Cairns I returned by steamer to Brisbane, the chief city of Queensland, nearly a thousand miles south. The botanical garden in Brisbane is not very large, but, as it was established many years ago, it contains many fine old trees and shrubs. The climate of Brisbane is subtropical, and there is a pretty large collection of palms and other tropical types, as well as those of more temperate climes. A small grove of giant bamboos, sheltering palms, and tree ferns was perhaps the most striking feature of the garden. Of the flowering shrubs, a fine lot of Indian Azaleas may be mentioned. These do particularly well in the coastal region of Australia, and were especially magnificent in the gardens in Sydney, on my return from the north.

The immediate vicinity of Brisbane offers little of botanical interest, but through the kindness of Mr. C. T. White, the government botanist, I was able to make two trips into the country, and thus had an opportunity to see something of the flora of South Queensland.

The first expedition was only a short distance from Brisbane, and was especially interesting, as it illustrated most beautifully the sharp line

separating the Eucalyptus forest from the "scrub" or rain forest. This seems to be due mainly to soil conditions, the rain forest being confined to the richer basaltic or alluvial soils. Some of the eucalypts of this region are very tall and beautiful trees, and valuable for timber. The following species were noted: *E. tereticornis*, *E. paniculata*, *E. propinqua*, *E. maculata*, and *E. tessellaris*. The nearly related *Angophora subvelutina* was also seen, and several of the characteristic Acacias—e.g., *A. Cunninghamii* and *A. Maidenii*.



FIG. 4. *Platycentrum grande*. Botanical Garden, Brisbane.

In the scrub, which included some eucalypts also, the most notable tree was *Araucaria Cunninghamii*. Other trees and shrubs noted were several species of *Flindersia*, *Cassia ovata*, *Canthium buxifolium*, *Piptella indica*, *Pseudomorus Brunonioides*, *Melaleuca* sp., *Vitex Lignumvitae*, *Ratonia tenax*, *Sideroxylon myrsinoides*, and several others.

The second excursion in South Queensland was to the Blackall Range, a mountainous district about 75 miles north of Brisbane. The railway to

the north is nowhere far from the coast and passes in places through patches of jungle of a decidedly tropical aspect. In the low ground, extensive groves of beautiful palms (*Archontophoenix Cunninghamii*) were seen, especially in the more northern districts.

After leaving the main line, we proceeded by a primitive tram line to Mapleton, at an elevation of about 2000 feet; but even at this height, palms were seen.

Most of the forest in the immediate neighborhood had been cut, but there were still remnants which showed what it had been. The forest here was of two sorts: "scrub," consisting almost entirely of true rain-forest types; and a mixed forest containing magnificent specimens of eucalypts (*E. microcorys*, *E. acmenioides*, and *E. pilularis*). With these were fine specimens of the related *Syncarpia laurina* and *Tristania conferta*, upon whose smooth trunk was growing an epiphytic orchid, *Dendrobium acuminatum*. Of the smaller trees and shrubs, the following were the commonest: *Casuarina torulosa*, *Rhodamnia trinervia*, *Schizomeria ovata*, *Trochocarpa laurina*, and *Eupomatia laurina*. Some attractive flowers were seen, but nowhere in Queensland were the flowers as abundant or as showy as in parts of New South Wales and especially in Western Australia. Several showy Papilionaceae may be mentioned, species of *Hovea*, *Glycine*, *Platylodium*, and *Kennedyia*, and an exceedingly pretty ground orchid. *Caladenia carnea*, was not uncommon. *Hibbertias* (Dilleniaceae) with showy yellow flowers were fairly abundant, and a true violet, *V. hederacea*, was about the only representative of the boreal flora.

Several species of *Loranthus* were seen, some with showy red and yellow flowers. There are many Australian species, and it is one of the most characteristic features of the Australian flora. Ferns were not especially abundant, but several species were common. Among these were *Davallia pyxidata* and *D. dubia*; *Pellaea paradoxa*, *Cyclophora serpens*, and *C. confluens*.

The country about Mapleton is fertile, and the climate is sufficiently tropical to permit of the successful cultivation of sugar cane, bananas, and oranges.

Not far from the village is a fine gorge into which a small cataract falls. This gorge has, up to the present, remained undisturbed, and offers an excellent example of the luxuriant rain forest which has been mostly destroyed elsewhere in the neighborhood. The steep walls of the gorge are clothed with a dense forest, in which only a few eucalypts were seen. Along the streams at the bottom of the gorge the aspect of the forest was quite tropical. Graceful palms and tree ferns fringed the streams, and there were a good many lianas, among them the southernmost representative of the rattans, *Calamus Mulleri*, which reaches well into New South Wales. On the trees were seen some interesting epiphytes, including orchids and ferns. The commonest of the orchids was a *Cymbidium*, not, however, in

flower. Of the epiphytic ferns, much the most striking were the two species of *Platycerium*, *P. grande* and *P. alcicorne*. Many young specimens of these were seen growing on rocks as well as on trees. Some aroids were seen, but these were not nearly so conspicuous as those in the scrub of North Queensland. A few specimens of the cycad *Macrozamia spiralis* were seen, but much smaller than specimens noted in New South Wales.

The most striking feature of this district was the "Bunya" pine, *Araucaria Bidwillii*, a much finer species than the more abundant *A. Cunning-*



FIG. 5. *Araucaria Bidwillii*, South Queensland. Photograph by Mr. C. E. S. Fryer.

hamii. *A. Bidwillii* is common in cultivation, and fine specimens are growing in various parts of California. The tree is decidedly restricted in its range, being confined to a rather limited area in southern Queensland. The Bunya mountains have extensive forests of this species, but outside this area they occur only as scattered individuals. Some very fine specimens were seen in the Mapleton forest, their great smooth domes of foliage overtopping the other trees. As the trees grow old, the smaller twigs fall off from the base of the horizontal branches, leaving them quite bare for most of their length, and the leafy twigs form a bunch of foliage at the tip. These Araucarias were greatly prized by the aborigines for their large, edible seeds.

Before returning to Brisbane, I stayed over night at Palmwoods, a station on the main railway line adjacent to a forest with fine groves of palms. These were practically all *Archontophoenix Cunninghamii*, and in the low, swampy ground formed pure stands of considerable extent. In the higher land, they were scattered among other trees. Perhaps no plant formation in Australia is more striking to the American botanist than these beautiful groves of tall, graceful palms. Few palms rival in beauty this species, with its smooth, slender trunk and crown of feathery foliage.

Along the railway embankment, in places, were masses of *Gleichenia linearis* and *Lycopodium cernuum*, a very common association in many of the warmer parts of the world. A very pretty blue iris was noted (*Pater-sonia* sp.), a very common genus in New South Wales and West Australia.

The railway from Brisbane to Sydney ascends to about 2000 feet 100 miles west of Brisbane, and then follows the table land southward. This table land includes the Darling Downs, a region of deep, rich, black soil, resembling the black "adobe" of California.

The precipitation in this region is rather uncertain, but in years of good rainfall, like that of 1921, heavy yields of grain, hay, and fruits, as well as dairy products, make this one of the richest agricultural districts in Australia. The country is an open one with no heavy forest, and at the time of my visit, in early August, the luxuriant growth of young grain and alfalfa gave promise of a bountiful harvest.

The Sydney end of the railway passes through a much less promising country and is practically at sea level. The soil is largely a poor, sandy one, and outcrops of rock are seen everywhere. There is the typical Eucalyptus forest, interspersed with golden-flowered wattles (*Acacia* spp.) and the characteristic Casuarinas and Melaleucas. Here and there, clumps of cycads (*Macrozamia*) were noted; and in a few places, where the soil was richer and moister, specimens of the Australian fan palm, *Livistona australis*, were seen. It was rather early for the showy flowers which abound in this region, but pretty pink *Boronia*s were recognized, as well as a handsome trailing leguminous plant, with fine blue flowers (probably *Hardenbergia*). Many "grass trees" (*Xanthorrhoea* sp.), another peculiar Australian type, were seen everywhere.

The heavy forest in Queensland is restricted to a relatively narrow strip adjacent to the east coast. Inland the conditions are not favorable for tree growth, and a very large portion of the 600,000 square miles of the state has no heavy forest growth. Maiden has summarized the situation as follows:

Westerly there are broken elevated table lands with rolling country beyond, much of it covered with open forest, of which *Eucalyptus* is an important constituent, and then sloping away to the centre of Australia are found conditions rarely favorable to tree-life.¹

NEW SOUTH WALES

As the ship enters the celebrated harbor of Sydney, one sees the numerous headlands and rocky promontories covered with the familiar *Eucalyptus*, interspersed with numerous characteristic low trees and shrubs, *Casuarina*, *Melaleuca*, *Leptospermum*, *Callitris*, and many others. The great city has spread of late years over most of the hills surrounding the harbor, and the native vegetation is rapidly disappearing, although in a few places there are parks or other reservations where it is being protected.

A walk over such areas as are still intact is full of interest. In the spring the sandy soil between the trees and larger shrubs produces many charming flowers—most of which are quite unfamiliar to the newcomer. On the rocky banks, especially where water seeps through, there are some very interesting ferns and liverworts, and sometimes huge sundews, giants of their kind. Some of the large shrubs at this time are also extremely ornamental: *Grevilleas* with pink or scarlet flowers; *Acacias*, masses of golden bloom; *Melaleuca* and *Leptospermum*, loaded with exquisite white flowers.

Approaching the wharf in Sydney, one catches a glimpse of the beautiful botanical gardens which extend down to the water. Adjoining the gardens, on a conspicuous elevation, is the picturesque Government House surrounded by stately Norfolk Island pines.

The botanical gardens in Sydney are extremely interesting botanically, as well as being very attractively laid out. The climate of Sydney is warm enough to permit the growth of all subtropical, and even of some tropical, plants. The garden is handicapped by a rather poor, sandy soil, and suffers at times from lack of water during the long, hot summer. This, however, was not evident in the spring, when an abundance of rain made everything look very fresh and attractive. Surrounding the garden on two sides is the "Outer Domain," a public park devoted to playgrounds and other similar purposes. A notable feature of this domain is an avenue of giant banyans, *Ficus macrophylla*, a native species known as Moreton Bay fig. On one side of the domain English oaks were planted, and had reached a very respectable size.

¹ Maiden, J. H. *Australian Vegetation*, p. 207. Federal Handbook for Australia, Melbourne, 1914.

In July, corresponding to our January, there was not very much in the way of floral display in the gardens. Poinsettias were in bloom, but looked rather pinched, not enjoying the cold westerly winds which then prevailed. Several specimens of an *Erythrina* (probably *E. indica*) were pretty well in bloom, their vermilion flower clusters being most conspicuous on the quite leafless branches.

In September, when the gardens were visited again, a great difference was noted. The spring display of flowers was about at its best, and included a great variety of bulbs and herbaceous bedding plants as well as many flowering trees and shrubs. The most beautiful feature of the gardens at this time was the magnificent display of Indian Azaleas, which seem to find the Sydney climate exactly suited to their needs. Huge bushes ten feet high or more were solid masses of gorgeous bloom, white, pink, and crimson.

Probably the collection of palms will first attract the attention of the botanist. These comprise practically all of the warm-temperate and sub-tropical species, but also include a considerable number of truly tropical genera, such as *Oreodoxa* and *Caryota*.

Another notable feature is the remarkably complete collection of cycads, nearly all the known genera being represented. Of the conifers, the fine old specimens of *Araucaria excelsa* take first place. One of these was planted in 1818 and is now over a hundred feet high.

Screw-pines, tree ferns, and a great variety of Australian and exotic trees and shrubs, as well as the more familiar things like Magnolias, Rhododendrons, flowering peaches, and crab apples, combined to produce most beautiful effects.

Still later, in November, another set of plants was in bloom; roses and various familiar herbaceous perennials were in full flower, and tropical-looking Bignonias and the blue Jacaranda made a gorgeous show.

The collection of succulents is an excellent one. American Cacti and Agaves, and the South African Aloes and Euphorbias, were equally at home. On some of the rockeries were great masses of a very fine native orchid, *Dendrobium speciosum*, with long racemes of handsome lemon-yellow flowers.

It was a great pleasure to meet again the director, Mr. J. H. Maiden, F. R. S., to whom the writer is indebted for many kindnesses.

The country about Sydney is rich in showy flowers, which are seen in profusion on the street flower-stands. Especial favorites are species of *Boronia* and the gorgeous "waratah" (*Telopea speciosissima*).

A visit was made to a point about 25 miles north, in a region which was still quite undisturbed. This was at an elevation of about 600 feet and was the usual open Eucalyptus formation with lower trees and shrubs interspersed, among which grew a profusion of beautiful low flowering shrubs and a small number of herbaceous plants including two or three orchids.

Pink-flowered *Boronias* and *Eriostemons*, belonging to the Rutaceae, were very abundant and beautiful; the Proteaceae were represented by

Banksias, some of which were small trees, and the lower-growing species of Grevillea, some with pretty pink flowers; Hakea, Persoonia, and Isopogon; *Lambertia formosa*, with brilliant scarlet flowers, was perhaps the finest of the Proteaceae. Yellow-flowered Hibbertias were very common, and other distinctly Australian types were Tetratheca (Tremandraceae), Dampiera (Goodeniaceae), and Comesperma, a very beautiful blue twiner belonging to the Polygalaceae. Various Papilionaceae, mostly species with showy yellow or red and yellow flowers, were very abundant, and played an important rôle in the gorgeous flower show.

Another most interesting trip was made by motor with Professor A. A. Lawson, of the University of Sydney, an old associate of the writer, to the National Park, one of the finest pieces of scenery in Australia. Much of the country between Sydney and the park is of the same character as that just described, and there were very beautiful displays of flowers in great variety. At one place, however, along the rocky banks of a stream, very different vegetation was encountered. On the dripping rocks were masses of liverworts and sundews, while in the sheltered nooks we found the interesting fern *Todea barbara* and the still more interesting *Tmesipteris*, whose life history was first made known through Professor Lawson's careful investigations.

The drive through the Bulli Pass took one back to tropical Queensland. The road was shaded by huge trees, covered with creepers, and masses of splendid tree ferns and tall palms (*Archontophoenix Cunninghamii* and *Livistona australis*), gave a most tropical appearance to the landscape.

The coast here is very picturesque, with sheer cliffs falling to the more level land at the shore, and from the top of the cliffs one can see the bold shore line with headland behind headland, in both directions, and the curved sweep of long beaches at their feet.

The return to Sydney through the National Park followed for several miles the gorge of a stream, and the luxuriant forest vegetation was much like that of the Bulli Pass. The forest was a mixed one; some of the eucalypts (probably *E. ptilularis*) were enormous, and the closely related *Angophora* sp. was not uncommon. *Eugenia* sp. and some others were of the true rain-forest type. Tree ferns and fan palms were abundant.

Of the flowers noted on this excursion, two stand out preëminently. One was a mass of the giant torch lily, *Doryanthes excelsa*, a plant related to our Agaves. From the cluster of broad leaves, five or six feet high, rises a stout scape, ten or fifteen feet high, bearing at the top a huge cluster of great scarlet lily-like flowers, surrounded by large red bracts. The other was a colony of the beautiful orchid, *Dendrobium speciosum*, growing on a rock ledge, and in fullest bloom.

One of the most interesting districts, botanically, in New South Wales is that of the Blue Mountains to the west of Sydney. The Blue Mountains form the edge of the elevated plateau which slopes westward to the plains

of the interior. The highest point is about 4000 feet above sea level, and in places there are deep and abrupt gorges cut in the sandstone rocks; and these gorges, which are well watered, support a rich and beautiful flora and provide fine collecting ground for the botanist.

In company with Dr. Lawson, I spent a couple of days at Wentworth Falls, in the immediate vicinity of one of the finest of the gorges. The plateau is covered with the usual open Eucalyptus forest with the accompanying vegetation like that of the lower country; but, as Wentworth Falls is over 2000 feet above Sydney, many plants at this time (September 10) were not yet in full flower.

Just above the gorge is a somewhat dry table land which has rather the aspect of an open moorland. The Eucalyptus trees were small and scattered, and most of the ground was covered with a thin chaparral-like scrub made up principally of Proteaceae of various kinds—*Banksia*, *Hakea*, *Grevillea*—and Leguminosae, including such showy genera as *Pultenaea*, with fine yellow flowers, blue *Hardenbergias*, scarlet *Kennedya*s, dwarf *Acacias*, and many others. Epacridaceae were also abundant, comprising species of *Epacris*, *Styphelia*, and *Leucopogon*, while several species of *Leptospermum* and a *Melaleuca* were the commonest of the Myrtaceae. *Boronia*s were abundant, and the somewhat similar *Tetratheca* displayed its pretty pink flower in many places. A curious little violaceous flower, *Ionidium filiforme*, was seen for the first time, and the brilliant blue *Lobelia gibbosa* was noticed in a few places, while a Campanula-like *Wahlenbergia* was not uncommon. In the damper spots, little *Drosera*s were found, but these were much better developed on the dripping rocks in the gorge. A very pretty little orchid (*Caladenia* sp.) was seen, and an attractive liliaceous plant, *Thysanotus tuberosus*, with lavender-fringed petals, was common.

A few specimens of *Callitris Muelleri* were the only conifers growing on the table land, but in the gorge, near one of the waterfalls, were seen several specimens of the extremely rare *Ptherosphaera Fitzgeraldi*, small bushes looking something like a dwarf juniper. Several species of *Casuarina* are found in the neighborhood of Wentworth Falls, and one, *C. nana*, which was very common on the table land, was only a foot or so in height.

An interesting but rare fern of the table land was *Schizaea bifida*, of which a few specimens were seen, growing in the barren, sandy soil.

The descent to the bottom of the gorge was full of interest. Well-made trails lead in various directions, and, as the gorge is a state reserve, the vegetation has been preserved intact and furnishes the botanist an unspoiled sample of the flora of the region.

The dryer slopes along the paths show much the same vegetation as the plateau above; but the sheltered and well-watered ravines and gullies exhibit a fairly tropical profusion of plant life. In many places water oozes out between the rock strata, and the dripping banks and cliffs harbor a wealth of curious and beautiful plants.

Proteaceae are extremely abundant in this region, over thirty species being recorded. First in size in the dryer soils were some half-dozen species of *Banksia*, the largest, *B. serrata*, being a very characteristic small tree, with thick, rough, corky bark and conspicuously serrated leaves. Few fresh flowers were seen, but the remains of the last year's inflorescences were conspicuous. The flowers are in dense oblong heads and are known locally as "honeysuckle." Several *Grevilleas* were common, and, in addition to the species observed in the open country above, there were other species as well as species of *Lomatia*, *Xylomelum*, *Petrophila*, and *Isopogon*. Several species of *Persoonia* were common, their glossy, bright-green leaves differing much from the foliage of most Proteaceae. The waratah (*Telopea speciosissima*) was not uncommon but not yet in full flower. About Sydney it was in full bloom, and the gorgeous blood-red inflorescence, surrounded by big scarlet bracts, make it one of the most magnificent of the many beautiful Australian flowers.

The characteristic Leguminosae and Myrtaceae, Casuarinas, and other shrubs were associated with the Proteaceae, and also several forms not seen at the top. Two Cunoniaceae were noted, viz., *Bauera rubioides*, a prostrate shrub with pink flowers, and *Callicoma serratifolia*, a tall shrub with large, serrate leaves.

The dripping rock walls supported a characteristic flora. In a mass of oozy material, partly made up of algae, were some most interesting liverworts, mosses, and ferns, as well as a good many flowering plants. Among the latter were some particularly beautiful heaths (*Epacris* sp.) with pink and white flowers, and several species of sundews abounded in these miniature bogs. One of these (probably *Drosera binata*) had leaves with petioles a foot or more in length and the forking laminae as broad as one's hand, divided into narrow segments covered with the characteristic tentacles. In contrast to this giant species were tiny flat, cushion forms more like those of northern bogs.

As elsewhere in Australia, herbaceous plants are not very much in evidence, and only a few of them, like species of *Ranunculus* and *Viola*, are familiar to the northern botanist. Two characteristic orchids were noted, one a species of *Pterostylis* with curious greenish flowers, known popularly as "green-hoods," the other a small epiphytic *Dendrobium* which, however, was not in flower.

The bottom of the gorges supports a fine forest, of somewhat the same type as that seen in the National Park. Magnificent eucalypts, with tall trunks and lofty crowns, were associated with the nearly related genera *Angophora* and *Syncarpia*, and the fine *Tristania nereifolia*. Two species of *Eucalyptus* are also found in this forest, as well as *Stenocarpus sinuatus*, belonging to the Proteaceae. *Ptilosporum undulatum* also occurs, and *Pomaderris elliptica* (Rhamnaceae).

The forest in these moist gorges is very similar to that in southern Queensland, and approximates the mixed rain forest of that region.

The Blue Mountains have an extensive and varied pteridophytic flora. Over forty species occur in the immediate vicinity of Wentworth Falls, and comprise a remarkable number of especially interesting species. On the wet rock slopes, and in the crevices, were two species of *Lycopodium*, *L. laterale* and *L. densum*, whose gametophytes can usually be found with a little searching. Two species of *Selaginella*, *S. uliginosa* and *S. Preissiana*, were abundant. *Tmesipteris tannensis*, whose interesting life history has recently been revealed, was found in a few places in the gorges, where Professor Lawson had frequently collected it. The ferns were very abundant, especially in the gullies and on the wet, rocky banks, but there were also a considerable number of more or less xerophilous species, like *Schizaea bifida* already mentioned. The ubiquitous *Pteridium aquilinum* is abundant, as it is in many parts of Australia. A second *Schizaea*, *S. rupestris*, was found on the wet rocks in company with *Lycopodium*, *Drosera*, and other bog plants, and on the somewhat less wet rocks was an abundance of *Gleichenia* spp. Four species occur in this region, and are very common and characteristic ferns.

The finest development of ferns, however, was in the damp, shady gullies near the bottom of the gorge. These fern gullies are extraordinarily beautiful. Clear streams form series of falls and cascades, and the fern growth is very luxuriant and includes some extremely fine species. The tree ferns are represented by two species of *Alsophila*, *A. australis* and *A. Cooperi*, which formed extensive groves of great beauty. Their slender trunks were sometimes twenty feet or more in height, and the crowns of fronds were very luxuriant and perfect. Seen from above, this carpet of interlaced giant fronds was extraordinarily beautiful.

Next to the true tree ferns, the magnificent fern *Todea barbara* was the most conspicuous. This sometimes forms a short trunk, but can hardly rank as a true tree fern. A second species, *T. Fraseri*, is very different in habit, and is often placed in a distinct genus, *Leptopteris*. This, like the two closely related New Zealand species of *Leptopteris*, grows in very wet places. It was growing where it was constantly wet with the spray of the falls, and its thin, translucent foliage much resembles that of the *Hymenophyllaceae*.

The latter were represented by several small species of *Hymenophyllum* and *Trichomanes*, but these are said to be much better developed in the cooler forests of the higher elevations.

Most of the widespread genera of *Polypodiaceae* are well represented, e.g., *Pteris*, *Lomaria*, *Blechnum*, *Asplenium*, *Doodia*, *Polypodium*, *Aspidium*, *Davallia*, and *Adiantum*. These were abundant in all the moister places, often completely carpeting the forest floor. There were not many epiphytic species noted, but on the whole both the fern flora and the bryophytes were much more in evidence than in most of the places visited in Queensland.

The bryophytic flora of the gorges was also extremely interesting. In

the boggy places along the trail were occasional patches of *Sphagnum*, and other conspicuous mosses were species of *Polytrichum* and *Dawsonia*.

Hepaticae abounded on the rocks and on the trunks of trees, and quite an extensive collection was made, which has not yet been worked up. As usual, the foliaceous species were the more common, but thallose types were abundant, especially in the shady fern gullies.

The most interesting find was *Podomitrium phyllanthus*, an Australasian species seen for the first time. This was very common, and a fine lot of material was secured. Very much like it in appearance were some of the species of *Pallavicinia* and *Symphyogyna*, which were also abundant. The *Pallavicinias* included species both of *Eupallavicinia* and *Mittenia*. *Aneura*, as is usual in such localities, was represented by a number of species, including one very large one which closely resembled *A. maxima* of the East Indies.

These gullies with their perpetual shade and moisture, and the corresponding luxuriant growth of forest trees and moisture-loving ferns and liverworts, and the barren sandy moorland on the table land a thousand feet or so above them, with its predominantly xerophytic vegetation, afford one of the most remarkable examples that has come to my notice of the differences in vegetation within a limited area due to the amount of moisture.

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